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# A retrospective study of functionality of patients with distal radius fracture after osteosynthesis with an LCP volar plate

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## ABSTRACT

Distal radius fractures are the most common fractures of the human skeleton, accounting for one sixth of all fractures. For his treatment, there are several surgical techniques and synthesizing materials that can be used, however, the use of a volar plate has been proven effective and haspresented few complications. **Objective:** Here was to make a retrospective study of thefunctionality of patients with distal radius fracture after internal fixation with an LCP volar plate that went through a rehabilitation program. **Method:** The sample consisted of 14 patients with unilateral distal radius fracture who underwent internal fixation with a 2.4 mm or 3.5 mm LCP volar plate who completed 1 year after surgery in 2010. The subjects were divided into two groups: affected group (n = 14), composed of fractured wrists; control group (n = 14) composed of the contralateral wrists. Measurements were made of active and passive range of motion (ROM) of the wrist, grip strength, pinch grip strength, and a questionnaire of disabilities of the arm, shoulder, and hand (DASH). The data was analyzed to compare the affected and controlgroups, through tests of significance of two independent samples for means. **Results:** The average for the DASH questionnaire was 10.63 points (± 12.23). For measures of grip strength, pinch grip strength, and ROM, there were no significant differences in comparison groups ($p > 0.05$). **Conclusion:** We concluded that after one year post-surgery, patients showed similar results when comparing the wrists, which shows a satisfactory recovery of functional status.

**Keywords:** internal fixators, radius fractures, rehabilitation

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## INTRODUCTION

Defined as those that occur within three centimeters of the radiocarpal joint,[1] distal radius fractures are the most common fractures in the human skeleton.[2] Colles, Barton, and Smith were the pioneers in the description of the distal radius fractures and their names are used as eponyms for such type of fracture.[2]

These fractures amount to one sixth of all the fractures attended to in emergency rooms and account for a high cost to the health systems.[1]

There is no epidemiological data from Brazil, but in the United Kingdom its incidence is of 9 for every 10 thousand men and 37 for every 10 thousand women.[3]

It is estimated that due to ongoing demographic changes, with the increasing growth of the elderly population and life expectancy, the incidence of this fracture should increase by 50% by 2030.[4]

The age bracket most afflicted is between 60 and 69 years old, with women being the main victims. However, in the last 20 years a peak of incidence has appeared among those aged between 20 and 40 years.[1,4]

The cause is generally the application of vigorous force, normally stemming from an industrial or sporting accident, high speed accidents, or falls from considerable heights.[4] Two trauma mechanisms are the most frequent in these fractures: the first is a fall with the wrist hyperextended, causing axial pressure on the anterior portion of the distal end of the radius; and the second is trauma with the wrist in flexion, resulting in compression force on the anterior portion and traction on the posterior position of the distal radius.[5]

There are many classifications for a distal radius fracture, among them we point out Frykman, Universal, and AO/ASIF. Oliveira Filho et al.,[1] consider the AO classification as the most complete. This classification takes into consideration the gravity of the bone injuries as the basis for treatment and evaluation of results. There are three basic types of fracture: extra-articular, partial articular, and complete articular.[1,2]

To decide on the best type of treatment for distal radius fractures it is necessary to consider the degree of instability, of reducibility, the fracture mechanism, and the associated injuries. Generally fractures without deviation or with stable reducible deviations are treated conservatively with cast immobilization. Irreducible fractures need surgical treatment with open reduction and internal fixation. However, in fractures with unstable reducible deviations internal or external fixation is indicated.[2]

The treatment of unstable fractures with the volar plate system is currently used for it yields less of a volar tilt and radial inclination.[5] We observed that the volar plate reduces the risk of irritating the tendons, which is one of the dorsal plate's biggest problems; few authors report any complications using this plate.[6]

Among the post-surgical complications of distal radius fracture found in the literature there are tenosynovitis of extensor or flexor tendon, reflex sympathetic dystrophy, carpal tunnel syndrome, consolidation delay, loosening of the implant, tendinous ruptures (long flexor or long extensor tendons of the thumb), malunion, neural lesions (median nerve), and radiocarpal and radioulnar arthrosis.[2,6]

Post-surgical rehabilitation is an integral part of the treatment of distal radius fractures dealt with surgically, and that is because there is an increased risk of long term loss due to the involvement of the wrist articulation.[7]

Restoring function has a direct influence on the quality of life, as well as the duration of the symptoms, and also the return to work activities, which deals with socioeconomic interests.[7]

The role of physical therapy intervention, after a period of post-surgical immobilization for this type of trauma, is to give back to the patient his or her range of movement and strength, making the patient apt for his or her functional activities. To that end there are many resources such as exercises, mobilization techniques, edema control, use of the heat and cold, electrotherapy, and orthoses, among other things.[8]

## OBJECTIVE

The objective of this study was to make a retrospective analysis of the functional state of patients with distal radius fractures submitted to open reduction and internal fixation with LCP volar plate who went through a rehabilitation program.

## METHOD

### Subjects

The sample was composed of patients with distal radius fractures submitted to osteosynthesis with LCP volar plates, one year after their surgeries and who were monitored at the Orthopedics Outpatient Clinic of the Clinical Hospital at the Ribeirão Preto School of Medicine, University of São Paulo (HCFMRP-USP). The individuals were divided into two groups:

Afflicted group (n = 14): composed of patients with distal radius fractures submitted to osteosynthesis of the limb afflicted with a volar plate. Control group (n = 14): composed of the limb contralateral to that with a distal radius fracture.

### Inclusion criteria

Patients of both genders were selected who were over 18 years old, who had a distal radius fracture submitted to osteosynthesis with a 2.4 mm or a 3.5 mm LCP volar plate.

### Exclusion criteria

Patients were excluded from the study who did not satisfy our inclusion criteria, as well as patients with inflammatory rheumatic disease or other co-morbidity of the wrist, with previous lesion or surgery, fracture due to an underlying disease (bone tumors, metastasis), dementia or cognitive disorders that would interfere in the rehabilitation process.

### Recruiting, collection, location, and team

All the patients submitted to osteosynthesis after distal radius surgery at the Clinical Hospital at the Ribeirão Preto School of Medicine, University of São Paulo (HCFMRP -USP) were referred to the Physical Therapy Outpatient clinic on their first post-surgical return to the Orthopedics Outpatient clinic (AOR-M).

In this first referral the patients were evaluated and oriented on post-surgical care and on the rehabilitation process. The patients were then referred for treatment to the Rehabilitation Center of the Clinical Hospital of Ribeirão Preto. The monitoring of all these patients was done by the Physical Therapy Outpatient clinic for the whole period of monitoring at the AOR-M. In each return new evaluations were made and necessary orientations were given.

### Procedures

To build a sample for this study, the authors reviewed the medical history of the patients with distal radius fracture submitted to osteosynthesis with LCP volar plate performed at the HCFMRP-USP, who completed one year post-surgery. Only the patients who fit the inclusion criteria described earlier were selected, and those who had complete

evaluation data with one year of post-surgery in their medical histories.

The evaluation of these patients included a functional evaluation of the wrist, in which measurements for range of motion (ROM) and muscular strength were made, and the application of the Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH).[10]

The range of motion (ROM) was evaluated on the afflicted wrist and on the contralateral wrist with the use of a goniometer.[9] The active and passive flexion and extension movements of the wrist, ulnar and radial deviation, and pronation and supination were measured.

Muscular strength was measured by the palmar prehension strength measurement through the Jamar® dynamometer in accordance with the American Society of Hand Therapists (ASHT) recommendations. For the measurements, the individuals were seated, with their feet on the ground, the shoulders adducted, the elbows flexed at 90°, forearm in neutral position, and the wrist with extension varying from 0 to 30°.

The measurements for pulp-pulp, three-point, and lateral pinch strength were made using the Preston Pinch Gauge® dynamometer, following the standardization recommended by the American Society of Hands Therapists (ASHT) described earlier, adding the thumb positioned in discreet flexion of interphalangeal joints and the remaining fingers not involved in the pinch in semiflexion.

Three measurements were made of palmar prehension and of each pinch with minimum interval of one minute between them, alternating between the non-afflicted side (contralateral) and the afflicted, recording final results by the average of the three trials in kilogram-force (Kgf).

The questionnaire applied (DASH)[10] is an instrument that evaluates function and symptoms of the upper limb seen from the perspective of the patient, the questionnaire does not depend on the affliction or its location, evaluating the upper limb while a functional unit. It has 30 self-applicable questions and two optional modules, one for sporting and musical activities, and the other for work activities; in this study items 1 to 30 were used.

The DASH items revealed the degree of difficulty in the performance of activities; the intensity of the pain, weakness, rigidity and paresthesia symptoms; the compromising of social activities; the difficulty sleeping and the psychological compromising, using as reference the week prior to the application of the instrument. The score of the items varies from one to five and the calculation of the total score is obtained through the sum of the 30 first questions, from that value we subtract 30 and divide the result by 1.2. The score can vary from 0 (without dysfunction) to 100 (severe dysfunction).

### Statistical analysis

For the analysis of data a comparison between the Afflicted and Control groups was made through the significance tests of two samples for averages. Based on the normal distribution model, we tested for the existence of significant differences between the recovery of two groups of patients, and we directly compared the p-value with the level of significance ($\alpha = 0.05$). For the statistical calculations the SPSS 8.0 program was utilized.

## RESULTS

Fourteen patients with unilateral distal radius fracture were included in the study. The sample showed an age average of 41 years (± 14.0), and was composed of 6 males (42.9%) and 8 females (57.1%). Five volunteers presented associated distal ulna fractures. As for the trauma mechanism, 57.1% of the sample (8 patients) fractured the distal radius due to a motorcycle accident, 28.6% (4 patients) due to falling on the ground, and 14.3% (2 patients) due to falling from a height. All the individuals were right handed, and in 6 of them the afflicted side was the dominant side (42.9%) and in 8, the other side was afflicted (57.1%). In relation to the synthesis material, only 3 volunteers used the 3.5 mm LCP plate (21.4%), while the other volunteers (78.6%) used a 2.4 mm LCP plate for the osteosynthesis. One hundred percent of the sample participated in a rehabilitation program after the osteosynthesis, and one year after surgery 11 patients (78.7%) returned to work regularly, one patient (7.1%) presented restrictions at work, one patient (7.1%) reported being unable to work due to pain, and one patient (7.1%) was unemployed at the moment of evaluation.

The average found in the DASH questionnaire for upper limb dysfunction was 10.6 ± 12.2 points. The score distribution of each volunteer can be seen on Figure 1.

As for the measurements of palmar prehension, the afflicted group presented a value of 24.1 ± 10.5 Kgf, while the control group presented a value of 31.1 ± 11.5 Kgf; in the comparison between the groups no significant difference was found *($p = 0.105$)*. For the pulp-pulp pinch strength measurements, the afflicted group presented a value of 4.7 ± 1.1 Kgf, and the control group presented a value of 5.5 ± 1.5 Kgf, without significant difference in the comparison between the groups *($p = 0.166$)*. In relation to the lateral pinch, the afflicted group presented the average value of 7.9 ± 1.9 Kgf, and the control group presented the average value of 8.5 ± 1.8 Kgf, also without significant difference between the groups *($p = 0.426$)*. Finally, the measurements of three-point pinch strength, the afflicted group presented a value of 6.4 ± 1.79 Kgf, and the control group presented a value of 7.3 ± 1.8 Kgf, without significant difference between the groups *($p = 0.204$)* (Figure 2).

The measurements for active and passive range of movement in flexion, extension, ulnar deviation, radial deviation, pronation and supination of the afflicted and control groups can be seen on Table 1. In the comparison between the groups no significant differences ($p > 0.05$) were found (Figures 3, 4, and 5).

## DISCUSSION

This study showed that one year after surgery, patients who had had distal radius osteosynthesis with LCP plate did not present significant differences in the variables evaluated (active and passive range of wrist motion, prehension forces, and pulp-pulp, lateral and 3-point pinch) when comparing the afflicted wrist with the contralateral one (control). This result indicates a recovery in the fractured wrist function some time after surgery.

The DASH questionnaire was created by the American Academy of Orthopaedic Surgeons (AAOS) together with the Council of Musculoskeletal Specialty Societies (COMSS) with the intention of being a scientifically valid, reliable, sensitive, and responsive instrument to symptoms and musculoskeletal functions, in view of the need for a measurement that could reflect the functional impact of a variety of diseases and damages to the upper limb, conceptualizing it as a functional unit.[10] The average DASH questionnaire score found in this study was 10.6 ± 12.2 points. Hudak, Amadio, and Bombardier classified the questionnaire score as excellent (< 20 points), good (20-39 points), regular (40-60 points), and bad (> 60 points); according to this classification, our sample presents an excellent functional state. Rozental & Blazar,

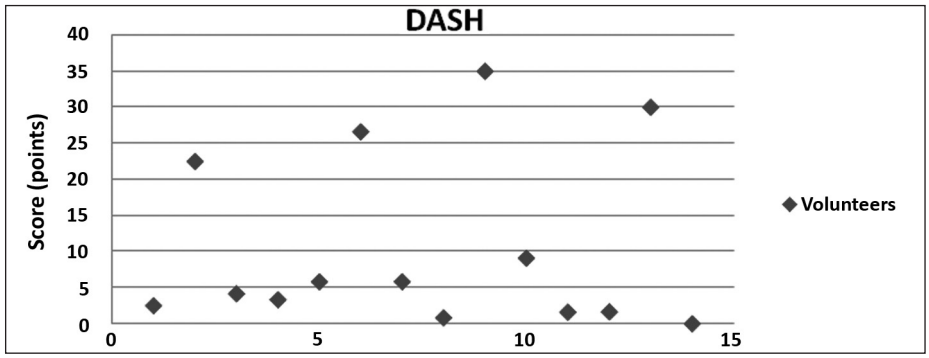


**Figure 1.** Distribution of volunteers' DASH scores in the study

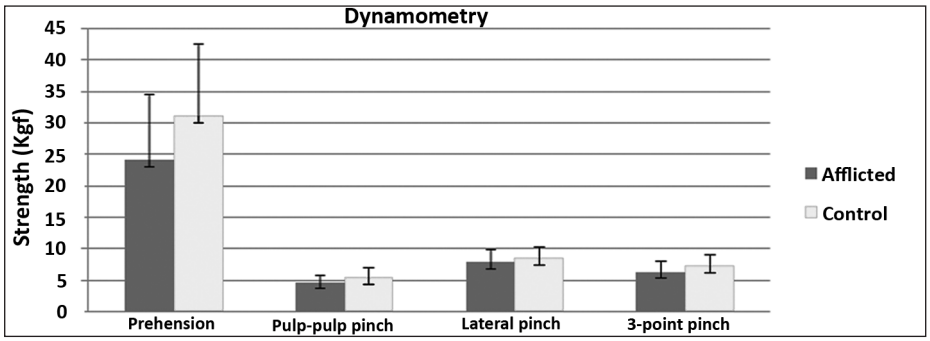


**Figure 2.** Dynamometry measurements comparison of the afflicted and control groups

**Table 1.** Wrist ROM measurements of the afflicted and control groups

| Wrist Movement | | Average (°) | Standard deviation | *p*-value |
|---|---|---|---|---|
| Active flexion | Afflicted | 66 | 11.77 | 0.120 |
| | Control | 73 | 12.21 | |
| Passive flexion | Afflicted | 78 | 11.20 | 0.054 |
| | Control | 85 | 9.30 | |
| Active extension | Afflicted | 59 | 14.22 | 0.110 |
| | Control | 67 | 12.94 | |
| Passive extension | Afflicted | 76 | 14.62 | 0.247 |
| | Control | 82 | 11.69 | |
| Active ulnar deviation | Afflicted | 31 | 9.11 | 0.090 |
| | Control | 37 | 9.14 | |
| Passive ulnar deviation | Afflicted | 39 | 9.48 | 0.193 |
| | Control | 43 | 8.60 | |
| Active radial deviation | Afflicted | 22 | 5.68 | 0.193 |
| | Control | 26 | 8.22 | |
| Passive radial deviation | Afflicted | 28 | 5.67 | 0.118 |
| | Control | 33 | 8.74 | |
| Active pronation | Afflicted | 87 | 6.97 | 0.546 |
| | Control | 85 | 11.60 | |
| Passive pronation | Afflicted | 88 | 5.60 | 0.860 |
| | Control | 88 | 4.97 | |
| Active supination | Afflicted | 78 | 17.40 | 0.612 |
| | Control | 81 | 17.92 | |
| Passive supination | Afflicted | 86 | 10.32 | 0.858 |
| | Control | 86 | 10.56 | |

while evaluating 41 patients submitted to the distal radius osteosynthesis with volar plate, in a follow-up period of 12 months, found an average score of 14 points in the DASH questionnaire.[11] A similar value in the DASH score (13 points) was found by Arora et al.,[6] who evaluated a population of 141 patients with distal radius fracture submitted to osteosynthesis with 2.4 mm LCP volar plate after a period of 12 months. Another study[4] shows a higher score (25 points) in the DASH questionnaire for a population of 80 patients with the same type of fracture submitted to osteosynthesis with volar plate.

In the palmar prehension strength evaluation, the Jamar® dynamometer was used, recognized as much clinically as in the literature as a standard instrument for measuring this force, yielding good indices of validity and reliability.[12] For this measurement, the recommendations of the American Society of Hand Therapists (ASHT) for the positioning of the individual were rigorously followed.

Our data showed that the average strength for palmar prehension in the afflicted group was 24.1 ± 10.5 Kgf, and in the control group it was 31.1 ± 11.5 Kgf, with no significant difference between the groups.

Caporrino et al.,[13] evaluated the palmar prehension strength in 800 normal individuals (1,600 wrists), dividing them into groups by gender, age bracket, and dominance to establish normality values for the Brazilian population. The general strength average for palmar prehension in the age brackets studied for males was 44.2 ± 8.9 Kgf, and 40.5 ± 8.5 Kgf for the dominant and non-dominant sides, respectively. For females, the average strength of palmar prehension, in the age brackets studied was 31.6 ± 7.5 Kgf and for the non-dominant side it was 28.4 ± 7.0 Kgf.

In our study, we did not group individuals into females and males, dominant and non-dominant, due to the small size of the sample (n = 14), which would lead to low representativeness of the data. To compare the values of normality, we subdivided the afflicted and control groups into males and females. In the male group, we found values of 30.8 ± 6.8 Kgf and 41.3 ± 6.9 Kgf for the afflicted and control sides, respectively. In the female group, we found values of 19.1 ± 10.3 Kgf for the afflicted side, and values of 23.5 ± 7.7 Kgf for the control side. The only normal value found for the Brazilian population was in the male group, control side; the others were below what was expected.

To establish the normality parameters for the pinch forces, a study in the Brazilian population was also made,[14] where 315 individuals

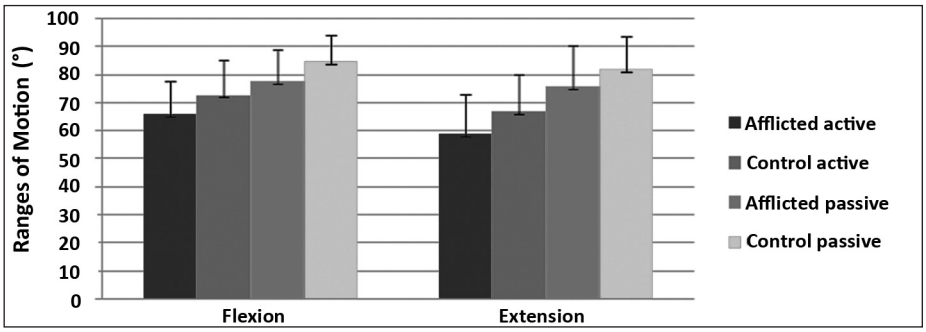


**Figure 3.** Comparison between the ROMs of the afflicted and control groups for the movements of flexion and extension, active and passive

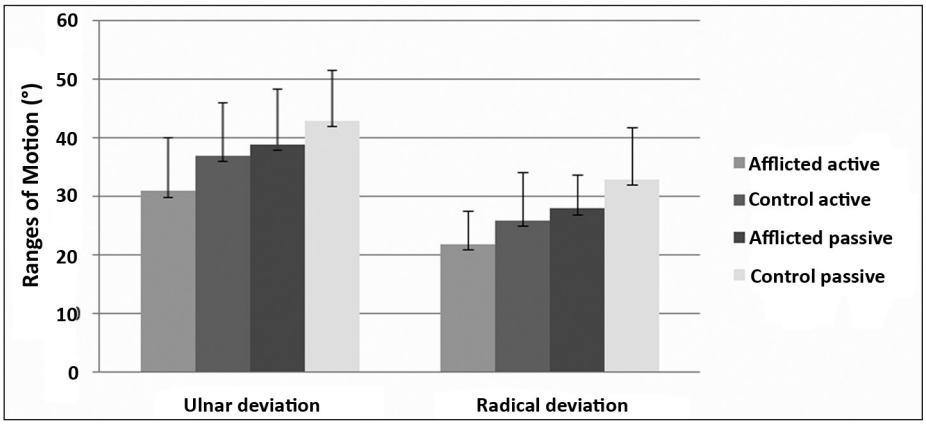


**Figure 4.** Comparison between the ROMs of the afflicted and control groups for the movements of ulnar deviation and radial deviation, active and passive

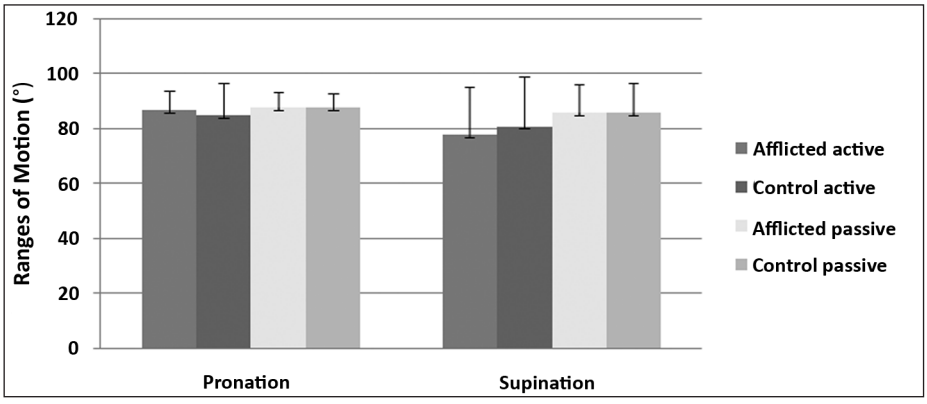


**Figure 5.** Comparison between the ROMs of the afflicted and control groups for the movements of pronation and supination

were evaluated and grouped by age bracket and gender. There was no significant difference between the pinch forces and the age brackets studied, and between the pulp-pulp pinch forces and the dominant and non-dominant hands, although we saw a slight difference (about 5% in favor of the dominant hand) in the lateral and 3-point pinches. For males the normality values found were 6.7 ± 1.8 Kgf, 8.5 ± 2.1 Kgf, and 9.9 ± 1.9 Kgf for the pulp-pulp, 3-point, and lateral pinches, respectively. For females the normality values found were 4.7 ± 1.3 Kgf, 6.0 ± 1.5 Kgf, and 6.7 ± 1.5 Kgf for the pulp-pulp, 3-point, and lateral pinches, respectively.

In our study, to compare the normality values, we subdivided the afflicted and control groups into males and females. In the male group for pulp-pulp pinch the values for the afflicted and control sides were, respectively, 4.9 ± 1.2 Kgf and 5.9 ± 1.7 Kgf; for the 3-point pinch the values were 6.8 ± 1.5 Kgf and 7.9 ± 1.8 Kgf; and for the lateral pinch the values were 8.9 ± 1.7 Kgf and 9.3 ± 1.5 Kgf. All these values found are below the normality values, however, the standard deviation was not considered for this analysis. In the female group for pulp-pulp pinch the values for the afflicted and control sides were, respectively, 4.6 ± 1.1 Kgf and 5.1 ± 1.4 Kgf; for the 3-point pinch the values were 6.1 ± 2.0 Kgf and 6.8 ± 1.8 Kgf; and for the lateral pinch the values were 7.2 ± 1.9 Kgf and 7.9 ± 1.9 Kgf. All these values were above the normality values, without considering the standard deviations.

As for the range of motion measurements, we find no significant differences in the comparison between the groups in any of the six movements evaluated, either for the active or the passive measurements. However, the passive flexion movements *(p = 0.054)* and active ulnar deviation *(p = 0.090)* presented the greatest deficiency when compared to the control group. Arora et al.,[6] found greater deficiency in the wrist's active flexion motion (28%), however, neither the passive movements nor the ulnar and radial deviations were evaluated. Such data suggests that during the rehabilitation process after osteosynthesis with a volar plate, emphasis must also be given to the wrist flexion gain and not only to the extension gain, as is already known in the literature.[15]

In the present study patients were included who had osteosynthesis with the 2.4 mm volar plate as well as with the 3.5 mm. The non-distinction between these synthesis materials seems not to affect the results of the study. Souer et al.,[16] compared the functional state of the patients submitted to osteosynthesis with the plates mentioned above for their distal radius fractures, through measurements of range of motion, muscular strength, pain, and the DASH and SF-36 questionnaires, in follow-up of 6, 12, and 24 months, and did not find significant difference in any of the items evaluated. Nevertheless, the wrist flexion movement at the 12-month follow-up and the movement arches for flexion and extension and pronosupination at the 24-month follow-up suggested a favorable result for using the 2.4 mm volar plate.

This study presents some limitations. Despite all the volunteers having been oriented on the rehabilitation process, the physical therapy program was not controlled. Furthermore, the associated lesions (distal ulna fracture) may have interfered with the results obtained. Finally, the study used a small sample, which makes it difficult to extrapolate the data for a larger population.

## CONCLUSION

In the sample analyzed we can conclude that, one year after surgery for osteosynthesis of distal radius fractures with a LCP volar plate, the patients showed results similar to the measurements of range of motion, prehension strength, and pinch for the afflicted and contralateral wrists, which shows a satisfactory recovery of the functional state.

## REFERENCES

1. Oliveira Filho OM, Belangero WD, Teles JBM. Fraturas do rádio distal: avaliação das classificações. Rev Assoc Med Bras. 2004;50(1):55-61.
2. Albertoni WM, Faloppa F, Belotti JC. Tratamento das fraturas da extremidade distal do rádio. Rev Bras Ortop. 2002;37(1/2):1-4.
3. Nazar MA, Mansingh R, Bassi RS, Waseem M. Is there a Consensus in the Management of Distal Radial Fractures? Open Orthop J. 2009;3:96-9.
4. Figl M, Weninger P, Liska M, Hofbauer M, Leixnering M. Volar fixed-angle plate osteosynthesis of unstable distal radius fractures: 12 months results. Arch Orthop Trauma Surg. 2009;129(5):661-9.
5. Gruber G, Gruber K, Giessauf C, Clar H, Zacherl M, Fuerst F, et al. Volar plate fixation of AO type C2 and C3 distal radius fractures, a single-center study of 55 patients. J Orthop Trauma. 2008;22(7):467-72.
6. Arora R, Lutz M, Hennerbichler A, Krappinger D, Espen D, Gabl M. Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. J Orthop Trauma. 2007;21(5):316-22.
7. Krischak GD, Krasteva A, Schneider F, Gulkin D, Gebhard F, Kramer M. Physiotherapy after volar plating of wrist fractures is effective using a home exercise program. Arch Phys Med Rehabil. 2009;90(4):537-44.
8. Kay S, McMahon M, Stiller K. An advice and exercise program has some benefits over natural recovery after distal radius fracture: a randomised trial. Aust J Physiother. 2008;54(4):253-9.
9. Marques AP. Manual de goniometria. 2 ed. Barueri: Manole; 2003.
10. Cheng HMS. Disabilities of the arm, shoulder, and hand-Dash: análise da estrutura fatorial da versão adaptada para o português [Dissertação]. Belo Horizonte: Universidade Federal de Minas Gerais; 2006.
11. Rozental TD, Blazar PE. Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. J Hand Surg Am. 2006;31(3):359-65.
12. Figueiredo IM, Sampaio RF, Mancini MC, Silva FCM, Souza MAP. Teste de força de preensão utilizando o dinamômetro Jamar. Acta Fisiátr. 2007;14(2):104-10.
13. Caporrino FA, Faloppa F, Santos JBG, Réssio C, Soares FHC, Nakachima LR,et al. Estudo populacional da força de preensão palmar com Dinamômetro Jamar. Rev Bras Ortop. 1998;33(2):150-4.
14. Araújo MP, Araújo PMP, Caporrino FA, Faloppa F, Albertoni WM. Estudo populacional das forças das pinças polpa-polpa, trípode e lateral. Rev Bras Ortop. 2002;37(11/12):496-504.
15. Smith DW, Brou KE, Henry MH. Early active rehabilitation for operatively stabilized distal radius fractures. J Hand Ther. 2004;17(1):43-9.
16. Souer JS, Ring D, Matschke S, Audige L, Maren-Hubert M, Jupiter J. Comparison of functional outcome after volar plate fixation with 2.4-mm titanium versus 3.5-mm stainless-steel plate for extra-articular fracture of distal radius. J Hand Surg Am. 2010;35(3):398-405.