



Comparison of palmar locking plate and K-wire augmented external fixation for intra-articular and comminuted distal radius fractures

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Objectives: This study was designed to compare the results of palmar locking plate and K-wire augmented external fixation in the treatment of intra-articular comminuted distal radius fractures.

Methods: The study included 30 patients with intra-articular comminuted distal radius fractures. Sixteen patients (11 men, 5 women; mean age 49±16 years) underwent open reduction and palmar locking plate fixation, and 14 patients (11 men, 3 women; mean age 35±10 years) underwent closed reduction and K-wire augmented external fixation. In both groups, eight patients had accompanying injuries. According to the AO/ASIF classification, there were four C1, 10 C2, and two C3 fractures in the locking plate group, and three C1, eight C2, and three C3 fractures in the external fixation group. For functional assessment, joint range of motion and grip strength were measured. The patients were assessed using the Gartland-Werley scale. Subjective functional assessment was made using the QuickDASH scale. On final radiographs, the presence of osteoarthritis in the radiocarpal joint was assessed according to the Broberg-Morrey criteria. The follow-up period was at least 12 months (26.1±6.1 months in the locking plate group, and 62.7±16.8 months in the external fixation group).

Results: Wrist flexion (p=0.012) and supination (p=0.003) degrees at final follow-up were significantly greater in the locking plate group. Other range of motion parameters were similar in the two groups. On final radiographic measurements, there were no significant differences between the two groups with respect to losses in palmar angulation, radial length, and radial inclination, and change in ulnar variance. The mean Gartland-Werley scores did not differ significantly (2.4±2.4 with plate fixation, and 2.0±2.8 with external fixation; p>0.05). The results were excellent in 11 patients (68.8%) and good in five patients (31.3%) with plate fixation. The results of external fixation were excellent in 11 patients (78.6%), good in two patients (14.3%), and moderate in one patient (7.1%). The mean QuickDASH scores and time to return to work were similar in patients treated with a locking plate and external fixator (QuickDASH score 2.4±3.0 and 2.9±5.4; 1.9±0.5 months and 2.1±0.7 months, respectively; p>0.05). The mean loss of strength compared to the healthy side at final follow-up was 3% in the locking plate group, and 5% in the external fixation group. Radiographic findings of stage 1 osteoarthritis were observed in four patients (25%) in the plate group, and in 11 patients (78.6%) in the external fixation group. There were no complications in the locking plate group. In the external fixation group, two patients (14.3%) had regional pain syndrome, three patients (21.4%) had superficial pin and wire tract infections, and one patient complained of adherence at entry sites of the fixator. Overall, nine patients (64.3%) expressed dissatisfaction with the external fixator.

Conclusion: Our results showed no superiority between the two treatment methods with respect to objective and subjective tools of evaluation. Palmar locking plate fixation was associated with full patient satisfaction. K-wire augmented external fixation can be used as a safe method in selected cases in which the severity of distal radius fracture would not allow palmar locking plate fixation.

Key words: Bone plates; external fixators; fracture fixation/methods; radius fractures/surgery; wrist injuries.

The treatment of distal radius fractures evolves over time thanks to technological advancements resulting in enhanced understanding of fractures and innovations in fixation materials. Different types of fractures occur in the distal radius depending on regional anatomy and type of injury.^[1-4] As there is no single method or material for the treatment of distal radius fractures, hand and upper extremity surgeons should be familiar with all alternatives. Determination of most appropriate methods and materials for different types of distal radius fractures is only possible through comparative studies. This study was designed to compare the results of palmar locking plate and K-wire augmented external fixation in the treatment of intra-articular distal radius fractures (AO type C). These two methods were evaluated in the light of the data obtained.

Patients and methods

A retrospective review of 42 patients was made, who were treated with palmar locking plate or K-wire augmented external fixation for intra-articular comminuted distal radius fractures (AO type C) at Kadıköy and Kozyatağı hospitals of Acibadem University between January 2001 and January 2008. Of these, 12 patients were excluded from the study due to loss to follow-up, address change, or inavailability at final follow-up. Thirty patients who responded and had their final follow-up evaluations comprised the study group.

The fractures were on the right side in 17 patients, and on the left in 13 patients. Etiologies were fall (n=15), fall from height (n=9), and traffic accidents (n=6).

Sixteen patients (11 men, 5 women; mean age 49 ± 16 years) were treated with open reduction using the palmar approach and fixed-angle titanium locking plate (Acumed, Beaverton, USA), while 14 patients (11 men, 3 women; mean age 35 ± 10 years) were treated with closed reduction under fluoroscopy, distraction with the Orthofix external fixator (Orthofix Inc., Texas, USA) and K-wire fixation for additional stability. In five of these patients in whom closed reduction could not be achieved, the fragments were reduced with mini incision and supported with a graft. In the locking plate group, grafting was applied in only one patient.

Time from injury to treatment was 2.0 ± 3.3 days (range 0 to 13 days) in the external fixation group, and 2.1 ± 3.7 days (range 0 to 14 days) in the palmar locking plate group. In the palmar locking plate group,

two patients had type 1 open fractures. One patient had median nerve neuropraxia due to fracture compression. Five patients had accompanying injuries which included radial head fracture with olecranon fracture, humerus fracture, talus fracture, first metacarpal fracture, and fifth metacarpal fracture with hip fracture. In the external fixation group, one patient had type 1, and one patient had type 2 open fractures. Two patients had median nerve neuropraxia due to fracture compression. Accompanying injuries were seen in five patients, including scaphoid fracture, L₁ vertebral fracture, elbow dislocation with ligament injury, contralateral radius fracture with frontal fracture, and patellar fracture with meniscus tear.

The fractures were assessed preoperatively by wrist radiographies and computed tomography and were classified according to the AO/ASIF (Swiss Association for the Study of Internal Fixation) classification system.^[1] The types of fractures were C1 (n=4), C2 (n=10), and C3 (n=2) in the palmar locking plate group, and C1 (n=3), C2 (n=8), and C3 (n=3) in the external fixation group.

All the fractures required surgical treatment due to intra-articular involvement or fragmentation.^[1] During surgery, a palmar Henry incision was used for the palmar approach.^[1-3] In the external fixation group, distraction with the Orthofix type external fixator was performed following closed reduction under fluoroscopy. The upper limit for distraction was the second finger reaching the distal palmar flexor fold with passive flexion. For additional stability, the fragments were reduced and fixed with 1.5 and 1.7 mm K-wires. The radioulnar joint was fixed with a transverse K-wire in one patient. For each patient, an average of three K-wires were used. The ends of the wires were left in the skin. Open reduction and grafting were performed with a mini incision for fragments that did not respond to ligamentotaxis or closed reduction due to contusion or excessive displacement. Four patients received a dorsal mini incision and one patient received a volar mini incision. In this group, carpal tunnel release was also performed in two patients who had acute median nerve compression.^[1-3]

Following surgery, a soft resting plaster wrist cast was used in the palmar locking plate group, that did not go beyond the metacarpophalangeal joint and reached the bottom of the elbow. Active finger exercises were started the day after surgery. Following

clinical and radiographic controls at weeks 2 and 4, the plaster cast was removed at week 4 at the latest depending on the condition of the patient, and rehabilitation was started with active and passive exercises with the support of a wrist brace. At the end of eight weeks, an exercise program for muscle strengthening was started depending on the level of union. The patients were allowed to carry load and do heavy work after completion of three months.

In the external fixation group, finger exercises were started the day after surgery. Wire ends were examined weekly for infection. After clinical and radiographic controls at 2 and 4 weeks, the K-wires used for support were pulled out between week 4 and week 6. When radiographic findings of solid union were observed, the external fixator was removed under sedation after an average of 7.8 ± 2.1 weeks (range 5 to 12 weeks) and rehabilitation with active and passive exercises were started with the support of a wrist brace. At the end of 12 weeks at the latest, an exercise program for muscle strengthening was started depending on the level of union. The patients were allowed to carry load and do heavy work after three months.

For objective functional assessment, joint range of motion was measured with a goniometer. Grip strength was measured using a Jamar dynamometer (Jamar, Preston, USA) and compared with the healthy side. The patients were assessed using the Gartland-Werley scale.^[5] Subjective functional assessment was made using the Turkish version of the QuickDASH

scale prepared by the Physiotherapy and Rehabilitation High School of Hacettepe University.^[6] The time needed to resume work or daily life was also assessed. Radiographic evaluations were conducted on wrist radiographs obtained in the early postoperative period and final follow-up. By comparison of radiographic anatomic measurements, losses in palmar angulation, radial length, and radial inclination, and the amount of change in ulnar variance were determined for each patient.^[7] On final radiographs, the presence of osteoarthritis in the radiocarpal joint was investigated according to the Broberg-Morrey criteria.^[8] Complications observed in the patients were recorded. In both groups, the follow-up period was at least 12 months, the mean follow-up being 26.1 ± 6.1 months (range 16 to 38 months) in the palmar locking plate group, and 62.7 ± 16.8 months (range 37 to 96 months) in the external fixation group.

Statistical analyses were performed using the NCSS 2007 & PASS 2008 Statistical Software (Utah, USA). Differences between the two groups were analyzed using the chi-square test, Fisher's exact test, Mann-Whitney U-test, and Student's t-test where appropriate. The results were evaluated with a 95% confidence interval, and a *p* value of less than 0.05 was considered significant.

Results

The mean age of patients in the palmar locking plate group was significantly higher than that of external

| | Palmar locking plate (n=16) (Mean±SD) | External fixator (n=14) (Mean±SD) | <i>p</i> |
|--|---|---|--------------|
| Loss of palmar angulation (°) | 2.3±2.9 | 4.4±3.8 | 0.089 |
| Loss of radial length (mm) | 1.2±0.8 | 1.1±1.1 | 0.689 |
| Loss of radial inclination (°) | 1.3±1.1 | 1.3±1.1 | 0.928 |
| Change in ulnar variance (mm) | -0.3±0.6 | -0.9±1.3 | 0.099 |
| Range of motion at final follow-up (°) | | | |
| Flexion | 66.3±6.1 | 56.8±11.4 | 0.012 |
| Extension | 64.7±5.3 | 64.3±12.5 | 0.913 |
| Pronation | 72.2±3.1 | 67.9±9.8 | 0.132 |
| Supination | 70.6±6.6 | 60.0±11.1 | 0.003 |
| Ulnar deviation | 29.1±4.2 | 31.1±6.3 | 0.304 |
| Radial deviation | 18.1±4.0 | 15.7±5.1 | 0.161 |

| | Palmar locking plate | | External fixator | |
|------------------------|----------------------|----------|------------------|----------|
| | Early period | Final | Early period | Final |
| Palmar angulation (°) | 6.5±6.0 | 4.6±6.8 | -1.2±5.4 | -5.6±8.1 |
| Radial length (mm) | 11.5±1.2 | 10.3±1.7 | 12.9±1.3 | 11.7±1.5 |
| Radial inclination (°) | 20.1±2.5 | 19.2±3.3 | 21±1.4 | 19.7±2.2 |
| Ulnar variance (mm) | 0.6±1.5 | -0.4±1.9 | 0.1±1.6 | -1.2±2.1 |

fixation cases ($p=0.007$). The two groups were similar with respect to gender ($p=0.689$).

In the palmar locking plate group, wrist flexion and supination degrees at final follow-up were significantly greater than those in the external fixation group (Table 1).

Radiographic measurements of both groups in the early postoperative period and at final follow-up are presented in Table 2. The mean loss in palmar angulation and change in ulnar variance were lower in the palmar locking plate group than those of external fixation patients, but these differences did not reach significance ($p=0.089$ and 0.099 , respectively). Losses of radial length and radial inclination did not differ significantly between the two groups, either (Table 1). Patients treated with a palmar locking plate and had wrist flexion and supination of less than 70° had a mean palmar angulation of -3.3° , radial length of 9.6 mm, radial inclination of 17.6° , and ulnar variance of -0.6 mm at final follow-up. The corresponding figures for patients treated with external fixation and had flexion and supination losses were as follows: palmar angulation -7.7° , radial length 11.6 mm, radial inclination 19.7° , and ulnar variance -1.7 mm. In both groups, the mean values of palmar angulation, radial length, radial inclination, and ulnar variance in patients with flexion and supination losses at final follow-up were lower than the overall means. In one patient in whom the radioulnar joint was fixed with a horizontal K-wire, supination and flexion of the wrist joint were 50° and 60° , respectively.

In the palmar locking plate group, the mean Gartland-Werley score was 2.4 ± 2.4 (range 0 to 6). The results were excellent in 11 patients (68.8%) and good in five patients (31.3%). The mean Gartland-Werley score in the external fixation group was 2.0 ± 2.8 (range 0 to 11), with excellent results in 11 patients

(78.6%), good in two patients (14.3%), and moderate in one patient (7.1%). No significant differences were found between the two groups with respect to the distribution ($p=0.339$) and means ($p=0.701$) of Gartland-Werley scores.

The mean QuickDASH score was 2.4 ± 3.0 (range 0 to 9.1) in the palmar locking plate group, and 2.9 ± 5.4 (range 0 to 18.1) in the external fixation group. The time required to fully resume work or daily activities was 1.9 ± 0.5 months in the palmar locking plate group, and 2.1 ± 0.7 months in the external fixation group. The two groups were similar with respect to time to return to work or daily activities ($p=0.267$) and the mean QuickDASH score ($p=0.734$).

The mean loss of strength compared to the healthy side at final follow-up was 3% in the palmar locking plate group, and 5% in the external fixation group.

Radiographic findings of stage 1 osteoarthritis were observed in four patients (25%) in the palmar locking plate group, and in 11 patients (78.6%) in the external fixation group.

Regional pain syndrome was seen in two patients (14.3%) in the external fixation group. This problem showed full resolution after rehabilitation. Three patients (21.4%) developed superficial pin and wire tract infections that were controlled with antibiotherapy. One patient complained of adherence at entry sites of the fixator. Overall, nine patients (64.3%) expressed dissatisfaction with the external fixator. There were no complications in the palmar locking plate group.

Discussion

The treatment of distal radius fractures has undergone changes owing to the advances in technology, and new approaches have emerged. Improved imaging methods providing better understanding of fractures and elucidation of the effects of injury type on



Fig. 1. (a, b) Distal radius fracture in a 44-year-old man. The fracture was so distal and comminuted as to not allow plating. (c, d) Early radiographs following open reduction and distraction with K-wire augmented external fixation. A proper alignment and stable fixation were achieved. (e) Radiographs of the patient at five postoperative months and (f) joint range of motion at 38 postoperative months. There were no complications, with the DASH score of 0, and an excellent Gartland-Werley score.

fracture formation and factors leading to instability have given way to new fixing methods and materials appropriate for the fracture, resulting in today's treatment options in distal radius fractures. These

methods can be classified as closed-indirect treatment methods, fragment-specific treatment methods, and fixed-angle plate implementations. Despite evolving and improving approaches, treatment goals remain

unchanged: restoring the joint surface to protect the joint cartilage, achieving radial alignment and height to preserve normal kinematics of the joint, providing mobility for maintenance of finger-wrist and forearm functions, and ensuring stability to protect length-alignment-joint surface congruency until recovery.^[9]

Different types of fractures may occur due to the anatomy of the distal radius and the effects of forces in different directions. It is often not possible to have a successful outcome using the same approach and materials for different types of fractures. While mechanical characteristics are important in fixator selection, the strategic placement of the selected materials may in fact be more important than the characteristics of these materials, particularly in intra-articular fractures.^[9] The best treatment option for different types of fractures may be determined by comparing different methods. Despite several difficulties in deriving generalized conclusions such as the differences in fracture types, age of patients, differences in bone quality, different assessment methods, and accompanying injuries in the same limb, most comparative studies report that neither of the two approaches is significantly superior to the other one.^[10-14] The studies conducted in Turkey, on the other hand, are mostly concerned with the results of external fixation.^[15,16]

In our study, apart from four parameters, no significant differences were found between the middle and long-term results of palmar locking plate and external fixation in intra-articular distal radius fractures. Functional assessment showed that wrist flexion and supination were better with palmar plate fixation; however, the two groups were similar with respect to grip strength loss, time to return to work, Gartland-Werley score, and QuickDASH evaluation. Radiographically, it was shown that palmar plating was associated with better correction of palmar angulation and protection of ulnar variance. This may be explained by the fact that distraction primarily occurs via palmar structures and that palmar locking plate provides a better support to the fracture. Traction alone in external fixation cannot correct palmar angulation due to the fact that ligamentotaxis primarily functions through strong palmar links. In this method, losses in palmar angulation may be seen during follow-up.^[1-4,17] As external fixation cannot fix a fracture as stable as seen by a locking plate and needs to be removed after a while, it cannot provide a firm basis against compression in the fracture. Indeed, in

external fixation applications, losses in palmar angulation may continue in the long term (even after the removal of the fixation).^[17] On the other hand, palmar angulation can be better corrected because of direct intervention provided by open reduction and palmar plate fixation. While the subchondral distal screws of the palmar locking plate provide support against palmar angulation losses, they also prevent compression of the fracture in the long term.^[1] The superior mobility achieved with the palmar locking plate may be attributed to the fact that these patients can start wrist movements earlier owing to firm fixation. All external fixators used in our study went beyond the joint and were not dynamized. Thus, mobility of the wrist joint was not allowed until the fixator was removed. This may explain mobility losses in the external fixation group. Losses in wrist flexion and supination were observed in patients who recovered with shortening and loss in palmar angulation, and in one patient in whom the distal radioulnar joint was fixed with a K-wire.

The use of palmar locking plate has become increasingly popular in recent years. However, this results from surgeon-related preferences rather than scientific data.^[18] Despite its advantages, there are still fracture types where palmar locking plate cannot be applied. Especially in comminuted very distal fractures that do not allow screw insertion, K-wire augmented external fixation may yield successful results (Fig. 1). In such fractures, however, external fixation and distraction alone cannot adequately reduce free intra-articular fragments that do not respond to ligamentotaxis. In this case, open reduction with mini incision allows restoration of especially the joint surface. Fixing the reduced fragments with additional K-wires and supporting the defect with a bone graft provide additional stability and speeds fracture union. Thus, the external fixator can be removed earlier, enabling early mobility and prevention of possible joint stiffness. Considering fracture types, removal times of the external fixators in our study were similar to those reported in previous studies.^[11,14,16] However, as mobility was started much earlier in the palmar locking plate group, less stiffness was observed in the wrist joint.

Reflex sympathetic dystrophy, fixation loss, pin tract infections, injury to the sensory branch of the radial nerve, and joint stiffness in the wrist are among known complications of external fixation. Excessive

distraction of the external fixator and prolonged fixation have adverse effects on the surgical treatment of distal radius fractures and can lead to many complications.^[19] It should be remembered that, in distal radius fractures, excessive distraction may not provide sufficient reduction of free fragments that do not respond to ligamentotaxis or involve the joint surface. Open or K-wire augmented reduction should be considered in these patients. Various criteria exist for the prevention of excessive distraction. A simple method is to determine the upper limit of distraction during surgery by the observation that all fingers, in particular the second finger, can touch the palm of the hand with passive flexion. Despite all precautions, two patients (14.3%) in the external fixation group experienced regional pain syndrome. In one of these patients, decompression was required during surgery due to acute median nerve compression. Both patients recovered fully after rehabilitation. Three patients (21.4%) in the external fixation group developed superficial pin and wire tract infections, which were controlled by antibiotherapy. One of these patients had prolonged fixation. Fixation materials that remain for a long time in the skin may lead to discomfort and infection. In order to prevent this, regular maintenance of fixation screws is needed. In particular, the Schanz screw in the distal radius may injure the sensory branch of the radial nerve. Insertion of the Schanz screw in this region through a small incision allowing visualization of the nerve may prevent injury. None of the patients in our study had sensory branch injury. The absence of complications in the palmar locking plate group points to the superiority of the method.

Improved methods of communication and the ease of reaching information allow patients to participate more in the treatment process. Likewise, patient preference is becoming increasingly more important in determining the treatment option for distal radius fractures. In our study group, nine patients (64.3%) reported dissatisfaction with external fixation. There were no significant differences between the two groups with respect to time to resume work or daily activities. Despite this, patients (particularly female patients) are not pleased with having to carry an apparatus on their wrist for two months, requiring regular maintenance and attracting public attention. This may explain the reason why increasingly more surgeons prefer to use the palmar locking plate method.

The findings of arthrosis in fewer patients in the palmar locking plate group may be attributed to the shorter follow-up period of this group.

One limitation of this study is the heterogeneity of the two groups. In this retrospective study, the two groups reflect diverse treatment options that have undergone changes and improvements over years. Prior to the development of palmar locking plate technology, external fixation with K-wire augmentation was preferred to the dorsal plate method in young patients with comminuted intra-articular distal radius fractures. However, palmar locking plate has made a reliable and stable fixation possible in the treatment of such fractures, regardless of the age of the patient. This may explain the differences between the two groups with respect to the mean follow-up times and age. Patient expectations and needs have also made closed and stable fixation methods more preferable over years.

The contemporary approach to intra-articular and comminuted distal radius fractures is to determine the best fracture-specific treatment method, with consideration of the main goals. It is thus necessary to detail the fracture by imaging methods (oblique radiographs, computed tomography and, where possible, three-dimensional reconstruction). This will enable a more strategic placement of the material, contributing to a stronger fixation. Patient preference is becoming an increasingly more popular factor in method selection. In our study, we found that palmar locking plate fixation was both reliable and free from complications. It was also associated with higher levels of patient satisfaction. Objective and subjective functional assessments, on the other hand, showed no significant superiority between K-wire augmented external fixation and palmar locking plate fixation in the medium and long-term follow-up. In comminuted and very distal fractures where palmar locking plate may not be feasible, K-wire augmented external fixation may be used successfully, with its but potential complications in mind.

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