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ORIGINAL ARTICLE

Combined palmar and dorsal plating of four-part distal radius fractures: Our clinical and radiological results

Birkan Kibar, MD

Department of Orthopedics and Traumatology, Haydarpaşa Numune Training and Research Hospital, Istanbul, Turkey

ABSTRACT

Objectives: This study aims to investigate the radiological and clinical outcomes of four-part intraarticular distal radius fractures treated with a volar anatomically locked plate and 2 mm low-profile plates using both the volar and dorsal approaches.

Patients and methods: This retrospective study included 20 patients (8 males, 12 females; mean age 47±12.1; range, 25 to 67 years) who received open reduction and internal fixation with combined volar and dorsal plating to treat complex four-part distal radius fractures (shaft, radial styloid area, dorsal medial facet, volar medial facet) between May 2016 and January 2019. According to Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification, all fractures were 2R3-C3. According to Melone classification, one fracture was type 1, seven fractures were type 2a, three were type 2b, three were type 3 and six were type 4. The mean follow-up time was 21±7.5 (range, 12 to 36) months.

Results: Union was achieved in all fractures. The mean tourniquet time was 103±12 (range, 90 to 130) minutes. The mean Disabilities of the Arm, Shoulder, and Hand questionnaire score was 10±9, and the mean Visual Analog Scale score was 2.1±0.9. According to Mayo wrist score, five patients had excellent, six had good, six had satisfactory and three had poor results. The mean grip strength was 25.2±9.2 (range, 15 to 40) kg and 78% of opposite side. Mean wrist flexion was 48.7°±15.3° (range, 30° to 80°), extension was 52.2°±17.2° (range, 25° to 80°), radio-ulnar deviation arc was 40.7°±6.9° (range, 30° to 55°), and mean forearm rotation arc was 152.3°±11° (range, 130° to 170°).

Conclusion: Plating method with a dual approach may be an alternative for four-part intraarticular distal radius fractures given its early mobility advantage and satisfactory functional and radiological results.

Keywords: Distal radius fracture, dorsal plating, dual approach, miniplate, palmar plating.

Intraarticular distal radius fractures account for 60% of all distal radius fractures.[1] Intraarticular fractures are most often fragmented and displaced in multiple planes. Articular comminution may include fragments in both the coronal and sagittal planes, as well as central impaction. The complexity of the fracture is often revealed by computed tomography (CT), which determines the treatment strategy.[2] Surgical treatment is recommended for distal radius fractures that cannot be primarily reduced or redisplaced. For these fractures, a bridging external fixator (BEF) can be applied and combined with limited internal fixation and K-wires. Reduction is achieved by the ligamentotaxis method and supported by percutaneous or mini-open methods. The disadvantages of this method are that the joint surface frequently cannot be restored, and early movement cannot be initiated.[3]

For good functional results, it is necessary to restore anatomy and achieve union. The volar plate technique is preferred by most surgeons because it is a relatively easy surgical approach, facilitates early onset of motion, and has fewer soft tissue complications compared to the use of dorsal plates.[4] With volar plates, reduction and fixation of the dorsal fragments are difficult. Many surgeons avoid dorsal plates because of the high incidence of complications

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Correspondence: Birkan Kibar, MD. Haydarpaşa Numune Eğitim ve Araştırma Hastanesi Ortopedi ve Travmatoloji Kliniği, 34668 Üsküdar, İstanbul, Türkiye.

E-mail: birkankibar545454@gmail.com

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such as extensor tendon irritation and rupture. Furthermore, adaptation of the plate to the radius anatomy is difficult.[5] In this study, we aimed to investigate the radiological and clinical outcomes of four-part intraarticular distal radius fractures treated with a volar anatomically locked plate and 2 mm low-profile plates using both the volar and dorsal approaches.

PATIENTS AND METHODS

Adult patients who received open reduction and internal fixation with combined volar and dorsal plating to treat complex four-part distal radius fractures (shaft, radial styloid area, dorsal medial facet, volar medial facet) at Haydarpaşa Numune Training and Research Hospital between May 2016 and January 2019 were evaluated retrospectively. Patients with a follow-up of at least one year and who replied to last control call were included. Patients with incomplete bone maturation (n=1), additional injuries in the same extremity (n=2), fractures extending into diaphysis (n=1), open and pathological fractures (n=2), and those who had previously undergone surgery on the same extremity (n=1) were excluded. Three patients were lost during the follow-up period, and a total of 20 patients (8 males, 12 females; mean age 47±12.1; range, 25 to 67 years) who met the criteria were included. The study protocol was approved by the Haydarpaşa Numune Training and Research Hospital Ethics Committee (Approval Date/No: 2020/54-2138). A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

According to Arbeitsgemeinschaft für Osteosynthesefragen (AO)/Orthopaedic Trauma Association (OTA) classification, all fractures were 2R3-C3. According to Melone classification, one fracture was type 1 (5%), seven fractures were type 2a (35%), three were type 2b (15%), three were type 3 (15%), and six were type 4 (30%).[6] The right side was affected in 12 patients and the left side in eight patients. There were no bilateral fractures. The dominant side was affected in 12 (60%) patients. The causes of the fractures were as follows: 11 (55%) falls, four (20%) traffic accidents, four (20%) occupational injuries, and one (5%) sports injury.

The ulna styloid process was fractured in 15 patients. All patients underwent preoperative CT to facilitate surgical planning. All patients were operated on by the senior author under general or axillary block anesthesia.

One hour before the surgery, 1 g of cefazolin was administered to all patients. All patients were placed on the operating table in a supine position. A pneumatic tourniquet was used at a pressure of 250 mmHg. First, a volar anatomically locked distal radius plate was applied with a standard volar Henry approach. Distal screws were applied as unicortical locking. To ensure radial inclination and radial styloid reduction, the brachioradialis insertion was loosened. Reduction and fixation of the volar facet served as a template for the other fragments. Then, a longitudinal incision was performed centered over Lister's tubercle. The extensor retinaculum was opened in the S shape to cover the plates. The tendons of the second, third, and fourth compartments were mobilized. The posterior interosseous nerve terminal branch was excised. Dorsal capsulotomy was performed to visualize the joint surface. In cases of impaction, articular fragments were disimpacted, fragments were reduced, and supported with allograft. Locked 2 mm miniplates were used for the dorsal fragments. First, the lunate facet and then the styloid process were reduced and fixed with miniplates. Then, the styloid process screws of the volar locked plate were applied. Extensor retinaculum flaps were placed and sutured to cover the distal of the plates. Extensor tendons were left on the dorsal aspect of the retinaculum. No intervention was performed to the ulna styloid process (Figure 1).

Allografts were used to support the joint surface and fill the metaphyseal defects in 13 patients, and no extra lag screws were used in any patients. No splints were applied after the operation. Active and passive finger and wrist motion resumed on postoperative Day 1. Ice packs were used for the first week for edema control. For the first three weeks, daily activities such as eating, pen holding, and dressing were allowed. After three weeks, the patients received a consultation from the physical medicine and rehabilitation unit, and a hand rehabilitation program was initiated for 1 h/day and five days/week; this included neuromuscular electric stimulation and stretching exercises until functional recovery was achieved. Full activity, including contact sports, was allowed once union was confirmed clinically and radiographically.

Follow-ups were performed at three and six weeks, and at three, six, and 12 months, and at last control. Last examinations were performed by a physical therapy and rehabilitation specialist in our hospital with experience in hand therapy,

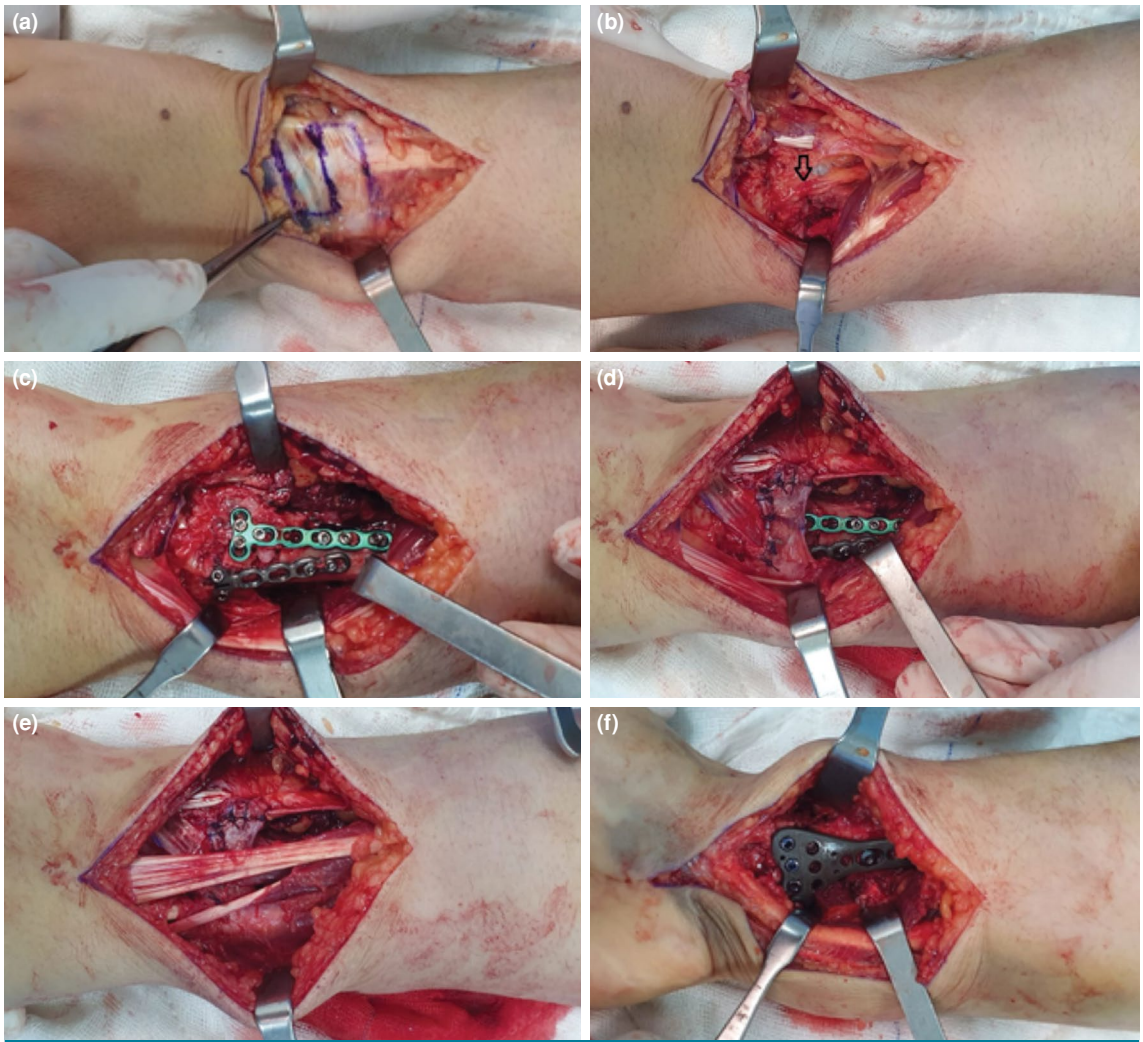

FIGURE 1. (a) Flap design of extensor retinaculum. **(b)** Posterior interosseous nerve terminal branch was shown with black arrow, and then this nerve was excised. **(c)** Application of dorsal 2 mm plates. **(d)** Extensor retinaculum flaps were used to cover plates. **(e)** Extensor tendons were left on dorsal aspect of retinaculum. **(f)** Volar approach to distal radius.

independent of the surgical team. Range of motion (ROM) for the wrist was measured with a goniometer. The Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire and Mayo wrist score were used for functional evaluation, and the Visual Analog Scale (VAS) was used for pain evaluation.[7-9] A Saehan hydraulic hand dynamometer (Saehan Corporation, Changwon, South Korea) was used to measure grip strength.

Using posterior-anterior and lateral radiographs, union was defined as cortical trabeculation and the formation of a bridging callus on the fracture line, with a lack of sensitivity in the fracture line upon palpation. The absence of a bridging callus after six months was classified as non-union. Measurements of palmar tilt, radial inclination, radial height, maximum articular step, ulnar variance, and carpal sag (translation of the carpus with respect to the long axis of the radius) were obtained. We measured carpal sag as the distance between the longitudinal axis of the lunate and capitate and the longitudinal axis of the radius on lateral X-ray (Figure 2).

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Paired sample t-tests were used for

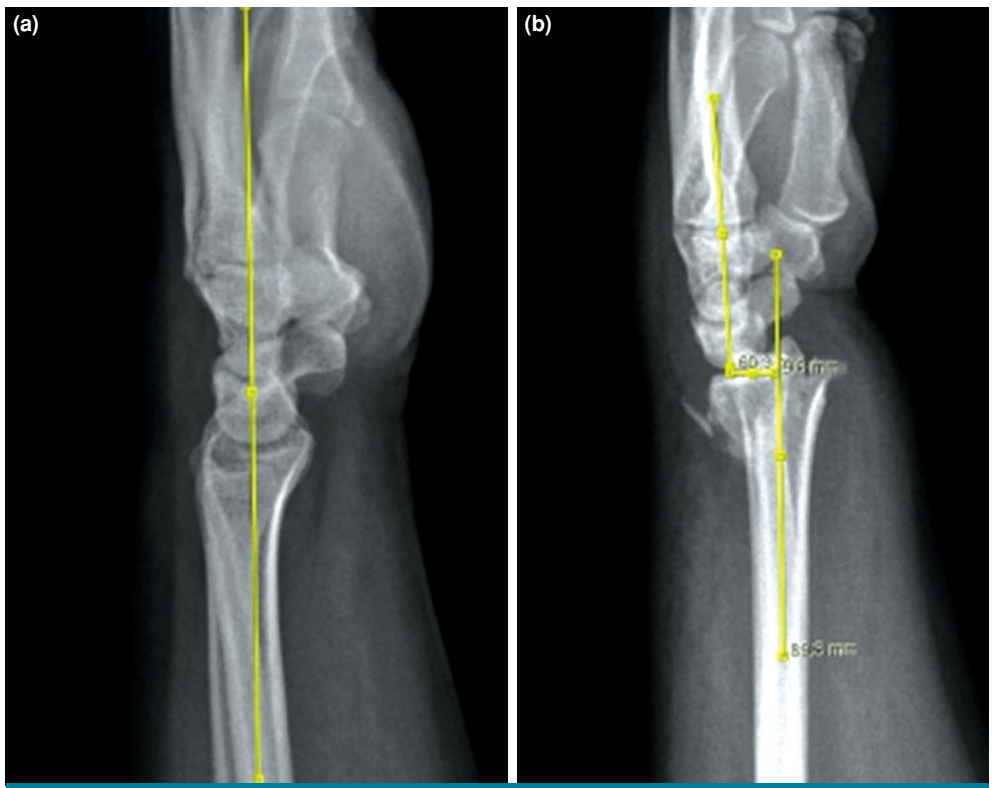

FIGURE 2. (a) Lateral alignment of normal wrist. **(b)** Carpal sag, dorsal translation of carpus with respect to longitudinal axis of radius.

parameter comparisons. A priory power analysis was performed based on the results of a previous study,[2] and 20 patients in our study provide a power of 67% at the 5% significance level. A p value <0.05 was considered statistically significant.

RESULTS

The mean interval between injury and surgery was 4.4±2.1 (range, 1 to 9) days. The mean duration of hospitalization was 5.6±2.3 (range, 3 to 12) days. The mean follow-up time was 21±7.5 (range, 12 to 36) months.

The mean tourniquet time was 103±12 (range, 90 to 130) min. The mean DASH score was 10±9 (range, 2 to 34) and the mean VAS score was 2.1±0.9 (range, 1 to 4). According to Mayo wrist score, five patients had excellent, six had good, six had satisfactory, and three had poor results. The mean grip strength was 25.2±9.2 (range, 15 to 40) kg and 78% of opposite side. Mean wrist flexion was 48.7°±15.3° (range, 30° to 80°), extension was 52.2°±17.2° (range, 25° to 80°), radio-ulnar deviation arc was 40.7°±6.9° (range, 30° to 55°), and mean forearm rotation arc was 152.3°±11° (range, 130° to 170°).

Union was achieved in all patients in the study (Figure 3). Mean volar tilt was 8.6°±5.2° (range, 0 to 17°), mean radial inclination was 21.1°±4.7° (range, 12° to 29°), mean ulnar variance was 0.9±1.6 (range, -3 to 3) mm, mean radial height was 10.5±3.3 (7 to 18) mm, mean carpal sag was 1.3±0.5 (0.4 to 2.2) mm, and mean maximum articular step was 0.8±0.5 (range, 0 to 2) mm. No reduction loss was observed after fixation.

Compared to the healthy side, there were significant decreases in wrist flexion, extension, grip strength, and radio-ulnar deviation arc, significant increases in ulnar variance, carpal sag, with no difference in pronosupination arc, volar tilt, radial inclination, and radial height. Details are listed in Table I.

No patient experienced implant irritation, implant prominence, implant migration, hardware loosening, malunion, osteonecrosis or plate/screw breakage. No patient experienced infection, tendon ruptures, major nerve injuries or hypertrophic scarring. No secondary surgery was required for any patient. Implants were not removed from any patient, and no neurovascular damage

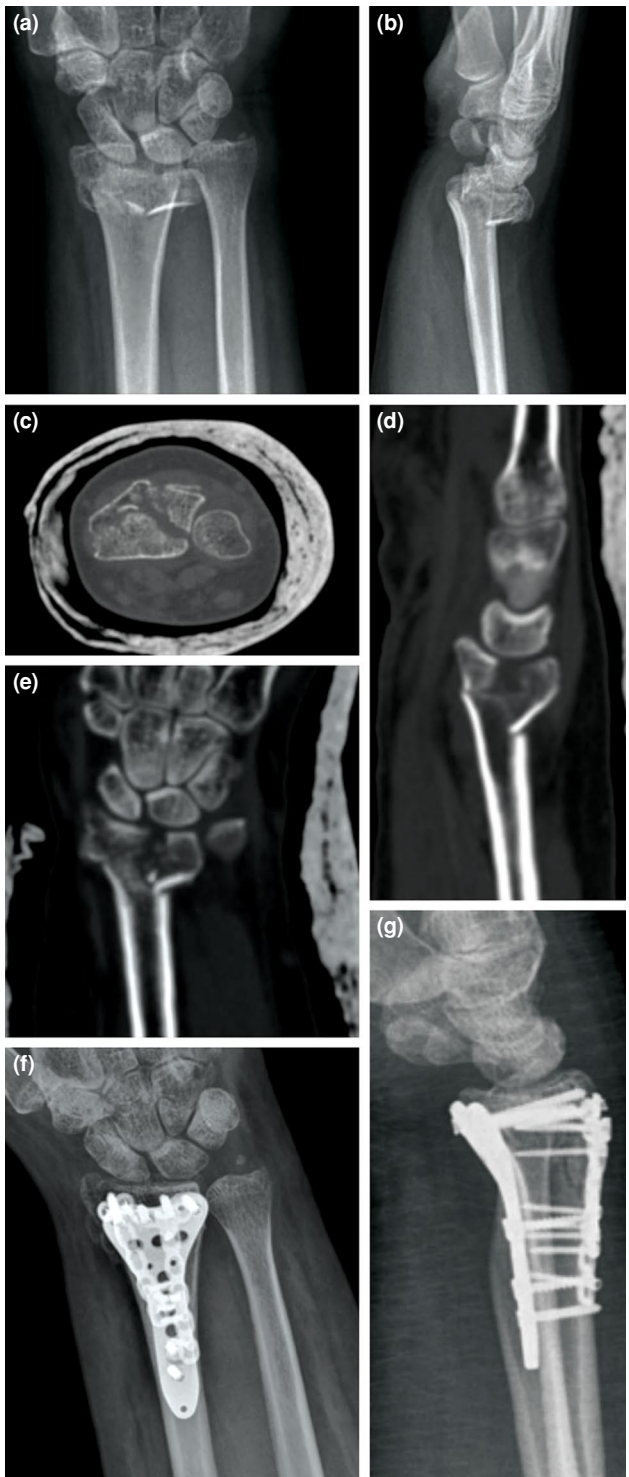

FIGURE 3. (a, b) Preoperative posterior-anterior and lateral X-rays of a 44 year-old female patient, who sustained comminuted fracture of distal radius. **(c, e)** Computed tomography scan, axial, sagittal, and coronal sections demonstrating comminution. **(f, g)** Postoperative sixth week posterior-anterior and lateral X-rays of same patient, after internal fixation with volar (distal radius volar anatomic locked plate) and dorsal (2 mm locked plate) plates, showing reconstruction of anatomy.

occurred. Two patients experienced transient reflex regional pain syndrome, which was improved by conservative treatment in both patients. Five patients had postoperative swelling and bullous lesions, all of which healed with elevation and local wound care.

DISCUSSION

This study included patients with four-part intraarticular distal radius fractures (shaft, radial styloid area, dorsal medial facet, volar medial facet) as described by Melone,[6] and we fixed the major fragments. We aimed to obtain superior ROM by fixing the major fragments and initiating motion early. It was difficult to view the joint surface and manipulate and fix the dorsal fragments by volar incision, and therefore we used dual incision. With volar incision, we stabilized the stout volar fragment with a distal radius locked anatomic plate that provided the length and alignment of the radius, achieved bone-bone contact and a provided template for additional stability for the other fragments. By using low-profile 2 mm miniplates to stabilize fragments in the dorsal side, we aimed to prevent tendon irritation and reduce the need for secondary surgery to remove implants. In addition, it was easier to adapt the miniplates to fracture fragments and the configuration of the radius, and the use of small screws allowed us to fix smaller fragments as well. The main purpose of the plates we used was the buttress effect to prevent the displacement of the fragments, and this effect was enhanced with distal locked screws.

A similar study was reported by Medlock et al.,[2] who treated 18 comminuted distal radius fractures with plates and used a combined dorsal and volar approach with a 2.4 mm fragment-specific plate for the dorsal fragments. They achieved union in all patients while restoring normal alignment and length of radius. No splints were applied postoperatively and mean ROM was 64%, and the average grip strength was 71% of the contralateral side. The mean quick DASH score was 29. According to the modified Green and O'Brien system, they achieved 10 good, seven fair and one poor results, one patient required split skin graft due to swelling of wrist for primary closure, another patient developed translation of carpus anteriorly, and no infection, tendon injury, major nerve or vessel injury were observed. Ring et al.[10] treated 25 C3-2 distal radius fractures using combined volar and dorsal approaches with plates. They achieved 54° extension, 51° flexion, 79° pronation, and 74° supination.

TABLE I
Comparison of functional and radiological results with healthy side

		Affected side		Healthy side		
	%*	Mean±SD	Range	Mean±SD	Range	*p***
Grip strength (kg)	76	25.2±9.2	15-40	33±8.7	22-47	0.01
Wrist joint extension (degree)	70	52.2±17.2	25-80	74±6.1	60-80	0.01
Wrist joint flexion (degree)	63	48.7±15.3	30-80	77.2±5.2	70-85	0.02
Wrist joint radio-ulnar deviation arc (degree)	67	40.7±6.9	30-55	60.5±3.5	55-65	0.04
Forearm supination-pronation arc (degree)	90	152.3±11	130-170	169±6.2	155-175	0.45
Volar tilt (degree)		8.6±5.2	0-17	9.5±3	5-14	0.45
Radial inclination (degree)		21.1±4.7	12-29	19.8±3.2	14-26	0.19
Ulnar variance (mm)		0.9±1.6	-3-3	-0.4±1.1	-3-1	0.02
Radial height (mm)		10.5±3.3	7-18	10.9±1.6	8-14	0.61
Carpal sag (mm)		1.3±0.5	0.4-2.2	0.4±0.3	0-1.1	0.01

SD: Standard deviation; * Percentage of affected side according to healthy side; ** Comparison between affected side and healthy side.

Average grip strength was 78% of the opposite side. They obtained an average 2° dorsal angulation, 21° radial inclination, 0.8 mm positive ulnar variance, and 0.7 mm joint incongruity. According to the Gartland and Werley system, 96% good and excellent results were obtained. Sagerfors et al.[11] treated 80 AO type C2 and C3 distal radius fractures with volar T-plate and dorsal Pi-plate, a splint was used for the first two weeks postoperatively, wrist extension was 74%, flexion was 70%, pronation was 94%, and supination was 90% of uninjured side. The mean DASH score was 19.4, VAS pain score was 0 at rest and 3 during activity, hardware removal was performed in 15 of 80 patients, three cases had postoperative infection, and there were no tendon rupture. Thus, our results using dual plating seem comparable with the literature. Despite the significant reduction in wrist movements when compared with the uninjured side in our study, this technique provided a functional wrist, and reduced motion can be considered favorable due to the complexity of fractures. Secondary surgery was common for implant removal in dorsal plates and tendon related complications were reported in both volar and dorsal plates.[12-14] We did not observe any complications such as tendon irritation, rupture, neuropathic complications, infection, non-union, or neurovascular injury. We used the extensor retinaculum to cover the distal part of the plates. There was no evidence of extensor tendon irritation, presumably because the plates were low profile and did not come into direct contact with the extensor tendon, and no secondary surgery for hardware removal was required. We translocated the extensor pollicis longus into the subcutaneous tissue and did not encounter any problems with this approach.

The general approach to intraarticular distal radius fractures has been external fixation. Reduction is achieved by the ligamentotaxis method and supported by percutaneous or mini-open methods.[3,15] In a study in which 21 AO type C distal radius fractures were treated with a BEF, one superficial infection and eight complex regional pain syndromes (CRPSs) developed, mean wrist flexion was 51.5°, extension was 46.8°, ulnar deviation was 16.3°, radial deviation was 12.7°, mean DASH score was 17.6, and mean grip strength was 35.1 kg.[16] Sharma et al.[17] applied external fixator to 15 intraarticular distal radius fractures, obtained 63° flexion, 60° extension, 69° supination, 66° pronation, 25° ulnar deviation, and 14° radial deviation. According to the modified Green and O'Brien scoring system, one excellent, five good, five fair, and four poor results were obtained and one pin tract infection was detected. Talmaç et al.[18] treated 30 intraarticular comminuted distal radius fractures with nonbridging external fixator (NbEF) and 31 with BEF. In NbEF group, 70° flexion, 60° extension, 15° radial deviation, 30° ulnar deviation, 80° supination, and 80° pronation were obtained, while in BEF group, 65° flexion, 45° extension, 10° radial deviation, 25° ulnar deviation, 75° supination, and 75° pronation were obtained. In NbEF group, pin tract infection was seen in three patients and CRPS was seen in four patients. In BEF group, pin tract infection was detected in three patients, CRPS in seven patients,

and radial nerve sensorial branch injury in one patient. Compared to external fixation, similar joint ROMs were observed with dual plating and external fixation. Combined plating is a technically demanding and more invasive procedure than external fixation; however, dual plating has the advantage of early mobilization.

In recent years, the importance of anatomical reduction and restoration of the articular surface have been emphasized. Open reduction and internal fixation became more important when the relationship between post-traumatic arthrosis and step deformity was demonstrated, with subsequent developments in plate technology. In a study comparing open reduction and internal fixation with closed reduction and external fixator in distal radius comminuted fractures, internal fixation gave better grip strength and ROM at one year, and also tended to have fewer malunions compared to external fixation.[19] Williksen et al.[20] treated 59 unstable distal radius fractures with external fixator and 52 with volar plates. Satisfactory outcomes were found for both groups at five years. The volar plate gave significantly better results for several clinical outcomes in the C2 subset analysis and 21% of the volar plates were removed.

Dorsal distraction plate fixation is considered an effective treatment option for unstable comminuted distal radius fractures. It is an internal fixator, which utilizes ligamentotaxis to help fracture reduction. Huish et al.[21] applied a dorsal distraction plate to 19 complex distal radius fractures with dorsal marginal impaction. The mean radial inclination was 20.5°, the radial height was 10.7 mm, ulnar variance was -0.3 mm, volar tilt was 7.9°, mean plate removal time was 80.5 days, and all fractures united prior to plate removal. In another study, Lauder et al.[22] treated 18 intraarticular comminuted distal radius fractures with dorsal bridge plates. Compared with the uninjured wrist, significant decreases in wrist flexion, extension, and ulnar deviation were observed. Grip strength was 86% of the uninjured side. There were two cases of postoperative regional pain and no cases of infection, tendonitis or tendon rupture. Richard et al.[23] applied an internal distraction plate in 33 patients with a comminuted distal radius fracture. All of the patients were over the age of 60. Again, all fractures united. The mean volar tilt was 5°. Ulnar variance was 0.6 mm and radial inclination was 20°. Wrist flexion was 46° and wrist extension was 50°. The authors emphasized that a distraction plate is an effective treatment method in osteoporotic comminuted distal radius fractures.

Although the dorsal plates were low profile and 2 mm, there was no reduction loss, secondary displacement, or unacceptable healing. We suggest that the obtained stability is sufficient to facilitate early movement. Biomechanical testing of the 2 mm double-plating technique on cadaver radii has shown superior initial stiffness compared with 3.5 mm T-plates and Pi-plates.[24] Jakob et al.[25] treated 74 distal radius fractures using the dorsal approach with two 2 mm plates. In that study, all fractures were united and 83% excellent, 14% good, and 3% fair results were obtained; four extensor tendinitis and five extensor ruptures developed, and implants were removed in 17 (23%) patients.

The main purpose of the plates we used was the buttress effect to prevent the displacement of the fragments, and this effect was enhanced with distal locked screws.[26]

The retrospective design of the study, small number of patients and the lack of a control group are the weaknesses of our study. Furthermore, long-term follow-up of the procedure is required to observe wrist joint degeneration and tendon rupture.

In conclusion, we believe that anatomical restoration is important in complex intraarticular fractures and plating method with a dual approach may be an alternative for four-part intraarticular distal radius fractures given its early mobility advantage, and satisfactory functional and radiological results.

Declaration of conflicting interests

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