Fixed-angle volar plates in corrective osteotomies of malunions of dorsally angulated distal radius fractures

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Objective: The aim of the study was to evaluate the radiological and functional outcomes of corrective osteotomy of malunited, dorsally tilted distal radius fractures, using fixed-angle volar plates.

Methods: We conducted a prospective study on 17 (10 male, 7 female; mean age: 41 years; range: 18 to 67 years) consecutive patients who were referred to our institution for treatment of a symptomatic malunion of the distal radius. The mean time from fracture to osteotomy was 4.4 (range: 2 to 7) months. Eight (45%) of the malunited fractures were on the dominant wrist. All patients were treated with an opening wedge osteotomy with a fixed-angle volar plate and cancellous bone grafting. Radiological measurements were performed pre- and postoperatively, including ulnar variance, radial inclination, and radial tilt. The degree of degenerative changes in the radiocarpal joint was assessed according to the criteria of Knirk and Jupiter. Forearm pronation/supination and wrist flexion/extension range of motion and grip strength were measured and compared with the opposite healthy side. Functional evaluation was performed with a Turkish version of the Q-DASH (Disabilities of the Arm, Shoulder and Hand Quick form) questionnaire.

Results: Mean follow-up evaluation was made at an average of 20.4 (range: 12 to 38) months. All osteotomies healed radiologically at mean time of 12.2 (range: 12 to 16) weeks. There was a significant improvement in the anatomical and functional parameters (p<0.05). The mean tilt of the radius improved from -27.4° of extension to 3.4° of extension and the mean radial inclination improved from 18.4° to 22.5°. The mean ulnar variance improved from 12.1 mm to <1 mm. Wrist flexion/extension range of motion improved from 100.8° to 144° and forearm range of rotation increased from 118° to 174.6°. Radial and ulnar deviation averaged from 22° to 27.3° postoperatively. According to the criteria of Knirk and Jupiter, 3 patients (17%) had Stage 2 degenerative arthritis. The average Q-DASH score improved from 26.5 to 5.7 and grip strength increased from 59.7% (17.5 kg) to 83.2% (24.4 kg) of the opposite side strength.

Conclusion: Fixed-angle volar plates provide a stable fixation after corrective osteotomies of the distal radius and might be a safer alternative to conventional fixation methods.

Key words: Cancellous bone grafting; corrective osteotomy; distal radius; fixed-angle plate; malunion; volar approach; volar locking plate.

Malunion is the most common complication following fractures of the distal end of the radius. While the malunion rate in surgically treated distal radius fractures is 10%, this figure increases to 23.5% in those fractures treated with conservative methods.[1]

Extra-articular deformities with dorsal angulation are common after malunions of distal radius fractures.[2-4] These angulations can produce abnormalities in the load transfer in radiocarpal and intercarpal joints, limiting wrist motions and leading to progres-

sive malalignment.[5,6] Loss of radial length may tense the interosseous ligament, which in turn causes distal radioulnar joint (DRUJ) incongruity. Consequently, the rotational movement of the forearm is restricted.[5-8] The joint incongruity may wear and eventually cause a degenerative tear in an initially intact triangular fibrocartilage complex. This can cause severe coordination problems and pain.[8]

Furthermore, increasing surface contact pressure due to extreme axial loading in the radiocarpal joint may lead to arthritis by causing deformations in the joint cartilage.[9] An active treatment should be performed to prevent this pathological process during the so-called "nascent malunion" period (2 to 10 months following trauma).[10-13] Patient complaints and expectations should be evaluated and surgical procedures to correct the anatomy and kinematics of the joint undertaken, where conservative treatment methods fail or are foreseen to be ineffective.[13] Corrective osteotomies as set out by Fernandez are one of the most preferred methods for this objective.[14-16] In this method, extra-articular deformities associated with malunion are corrected through metaphyseal open wedge osteotomies performed on the angulated side of the radius. The bone cavity created by the osteotomy is filled with autogenous cortical and spongious bone graft and stabilized with plate and screws.[13,17] In cases where DRUJ congruity cannot be achieved, treatment is complemented with surgical interventions on the ulnar side.[13,18] In recent years, treatment of the malunion with volar fixed-angle plates, regardless of the angulation direction of the malunion, has been recommended. With the very limited number of studies on this subject, however, further studies are required.[19-23]

In this prospective study, radiological and functional outcomes of corrective osteotomies using fixed-angle volar plates on dorsally angulated distal radius fracture malunions were assessed.

Patients and methods

A total of 17 patients (10 males, 7 females) who admitted to our clinic with dorsally angulated distal radius malunions were included in this prospective study conducted between 2005 and 2009. Patients' mean age was 41 (range: 18 to 67) years. Malunions observed in the radiographs taken upon the patients' initial admission were evaluated in accordance with

AO/ASIF (Swiss Association for the Study of Internal Fixation) classification.[4] According to this classification, there were 5 Type C fractures (29.4%), 2 Type B fractures (11.8%), and 10 Type A fractures (58.8%). Of the 17 total fractures, the left side was involved in 11 (64.7%) and the right side in 6 (35.3%), with 8 fractures (47%) being on the dominant wrist. Accompanying pathologies included dynamic scapholunate dissociation in one patient (5.8%) and radiocarpal arthritis in another (5.8%). All fractures were caused by falling injuries, with a mean time from fracture to the malunion diagnosis of 4.4 (range: 2 to 7) months. The patients had been originally treated using closed reduction and circular casting.

Criteria for enrolment in the study were, (1) a <1 mm step-off on the radiocarpal joint surface; (2) a >15° permanent dorsal angulation in the original fracture site; (3) a <20 mm positive ulnar variance; and (4) clearly apparent deformities, as well as complaints associated with inefficiency in daily activities (pain, restricted wrist motion and reduction in grip strength).

Comparative bi-directional wrist radiographies were taken in order to conduct preoperative planning for radiological correction. Radial inclination angle and ulnar variances were measured from the anteroposterior radiographs taken with the shoulder joint positioned in 90° of abduction, the elbow joint in 90° of flexion and pronation and the wrist in a neutral position. Radial tilt angles of the side grafts on the wrist were measured.[24] Early-term postoperative radiological controls were conducted at 6-week intervals, starting from the first day until the radiological healing of the fracture, which was regarded as the surface integrity of the volar and dorsal cortex in the osteotomy site. Radiographs taken in the 12th follow-up month were used for the post-treatment radiographic measurements. Q-DASH (Turkish version of Disabilities of the Arm, Shoulder and Hand Quick form survey) was used for functional evaluation.[25] Functional follow-up began after the fracture healing was attained on the osteotomy site. Follow-up was done in the 3rd, 6th and 12th months. When the evaluation process of the study was finalized in August 2009, the patients were called for a functional and radiological assessment. Knirk and Jupiter[26] criteria were used for evaluating the degenerative changes involving the radiocarpal joint. Wrist flexion/extension, radial/ulnar deviation, and forearm supination/

pronation movements were measured using a goniometer both preoperatively and during the follow-up. Gripping strengths of both hands were measured with a dynamometer (Jamar; Therapeutic Equipment Corp, Clifton, NJ, USA). The average value from three maximum gripping attempts was used in the evaluation.

The applied surgical method was similar to that described by Prommersberger and Lanz.[15] Henry's[23] volar approach was used to access the distal radius. To facilitate the intervention, the brachioradialis tendon was partially released from its attachment point at the radial styloid. The preoperatively planned osteotomy site was accessed at 2.5 cm proximal to the joint line or the original fracture site. The osteotomy plate was placed to allow the insertion of at least three screws in the proximal part of the planned osteotomy. The fixed-angle volar plate was placed in the pronator fossa, parallel to the joint line at the anteroposterior plan and temporarily fixed with K-wires. Once the distal orientation was determined, a screw guide was inserted into the plate and a central screw hole opened in the distal part of the osteotomy. The plate was then removed from the surgery site. Using a K-wire and a 2.0 mm drill head, holes were drilled in the direction of dorsal cortex to thin both cortices and a crescentic osteotomy was performed with the osteotomes. The dorsal periosteum was released by means of a periosteal elevator, with the distal part of the osteoto-

my mobilized. The plate was then placed on the bone and fixed. Using the plate as a joystick under radioscopic monitoring, sagittal and frontal plan corrections in the osteotomy site were performed (while the anatomic structure of the plate allows the radial tilt angle to be readily corrected, radius length and inclination could be obtained by means of traction performed in the ulnar deviation). Meanwhile, the position of the most proximal and the longest screw hole was marked with a K-wire or a surgical marker. At the same time, cancellous bone grafts taken from the iliac crest of the same side were placed in the osteotomy site. The plate was then positioned on the bone and fixed into the previously marked proximal screw hole, using an appropriate single cortex screw. In cases where it was not possible to ensure sufficient radius length under fluoroscopic control, the proximal screw was removed and the correction maneuver was repeated (Fig. 1). Once the other screws were placed, the remaining bone grafts were inserted in the osteotomy site by a radial approach to the flexor carpi radialis muscle. Subsequently, the pronator quadratus muscle and the other tissue layers were repaired respectively. Cancellous bone graft, harvested from the iliac crest, was used as autologous bone graft in all patients. A 2.4 mm LCP® Distal Radius system (Synthes, Paoli, PA, USA) and a 2.3 mm Acu-loc® (Acumed, Hillsboro, OR, USA) were used as volar fixed-angle plates in this study.
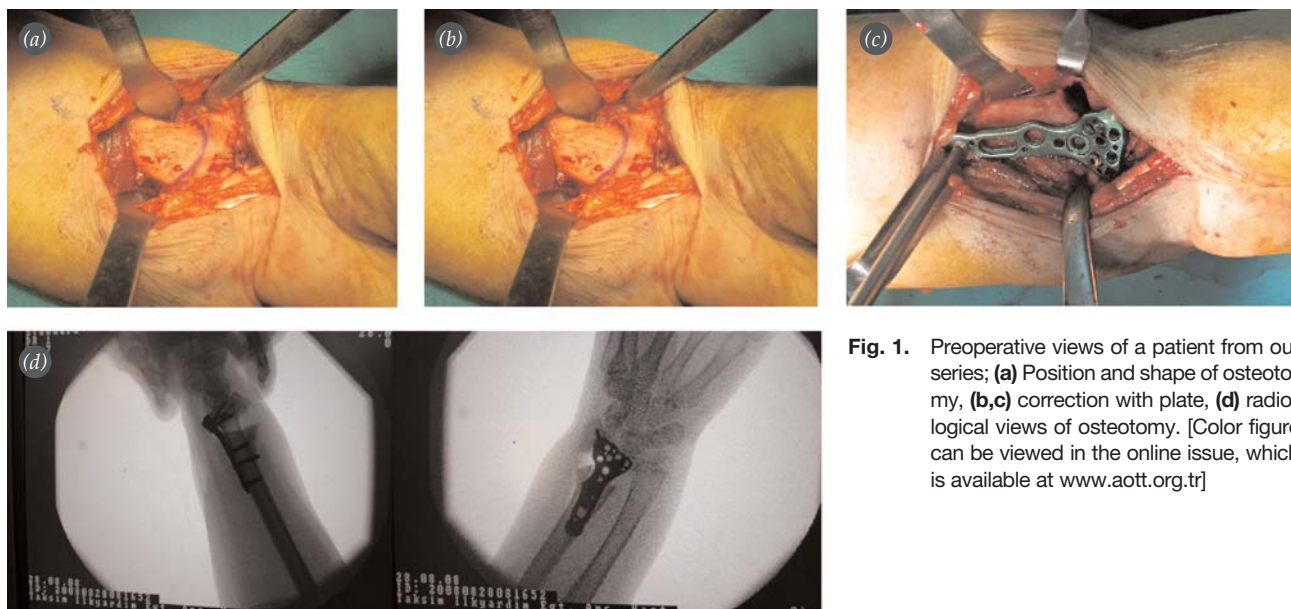

Fig. 1. Preoperative views of a patient from our series; **(a)** Position and shape of osteotomy, **(b,c)** correction with plate, **(d)** radiological views of osteotomy. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

The wrist was immobilized with a cast brace during the 2-week period from the surgery to the removal of the sutures. The brace was then removed and range of motion exercises were begun. Passive wrist flexion/extension exercises were started at the end of the fourth week and resistive strengthening exercises started after 6 to 8 weeks.

Student's t-test under the Medcalc 10.0 (www.medcalcturkey.com) software was used for the statistical evaluation of the data. The results are reported as the mean, range; and a standard deviation (SD) of p values less than 0.05 was considered statistically significant.

Results

Radiological healing was achieved in all osteotomies at a mean of 12.2 (range: 12 to 16) weeks. Patients were followed up for a mean period of 20.4 (range: 12 to 38) months.

While the mean preoperative ulnar variance was 12.1 (SD: 3.8) mm positive, a mean positive value of 1 (SD: 2) mm (p<0.001) was only detected in 4 patients (23.6%) (Figs. 2 and 3). There was no statistically significant variation in the radius tilt angle obtained in the final controls; 3.4° (SD: 2.3) when compared to that of the healthy side; 2.2° (SD: 2.5) (p=0.24). A significant improvement was observed in the tilt angle after the operation from -27.4° of extension to 3.4° of extension (p<0.0001). The preoperative radius inclination angle which was 25° (SD: 2.5) in the healthy side and 18.4° (SD: 6.3) in the malunion side regressed to 22.5° (SD: 2.1), following the surgery (p<0.01) (Table 1).

Articular ranges of motion obtained during the final controls are shown in Table 2. The preoperative mean grip strength of 17.5 kg (SD: 6.9; 59.7% of the healthy side) was measured as 24.4 kg (SD: 8.2; 83.2% of the healthy side) in the final follow-up. There was a statistically significant variance between both measurements (p=0.012). The preoperative Q-DASH score of 26.5 points (SD: 8.9), decreased to 5.7 points (SD: 8.3) as a result of the treatment (p=0.001). While 14 patients (82.3%) had a Q-DASH score of over 20 points before the surgery, there were only 2 patients (11.7%) with these scores after the surgery.
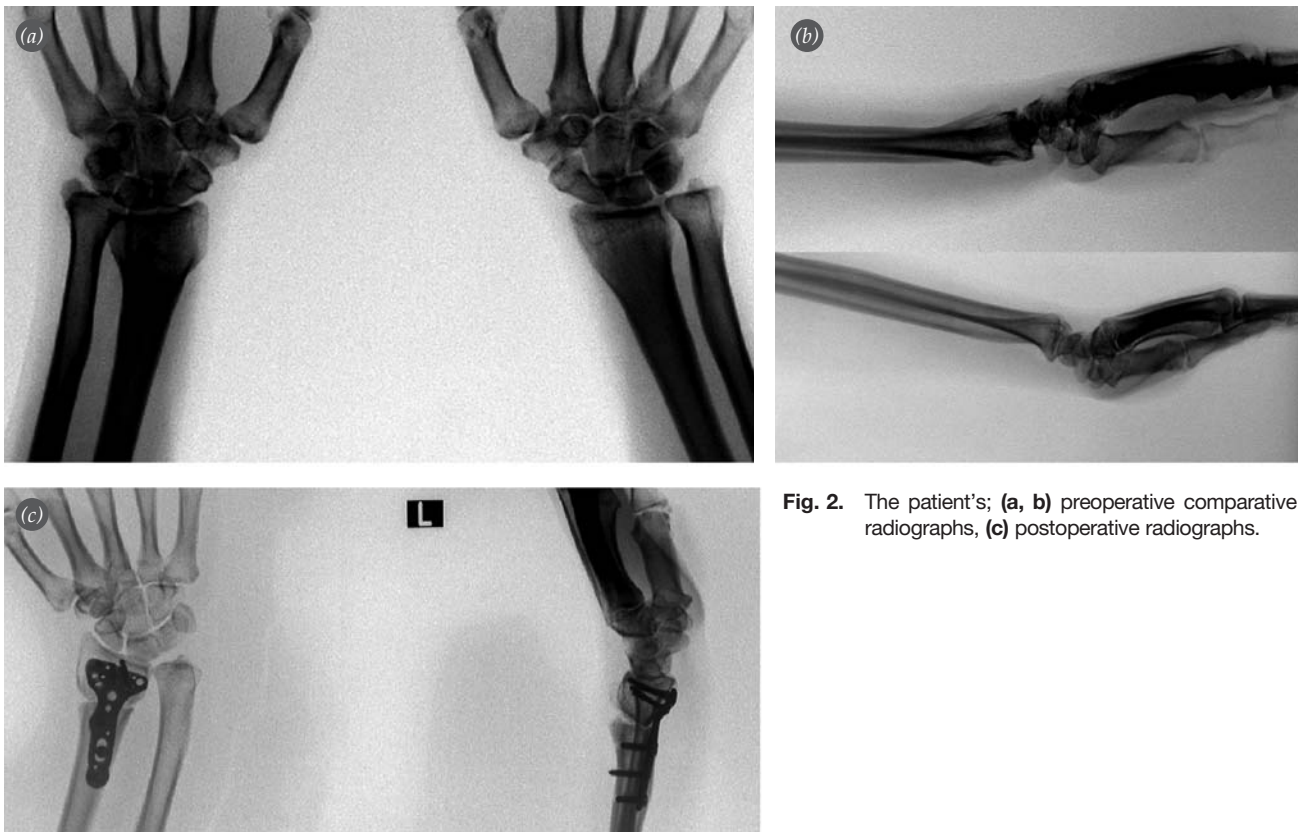

Fig. 2. The patient's; **(a, b)** preoperative comparative radiographs, **(c)** postoperative radiographs.
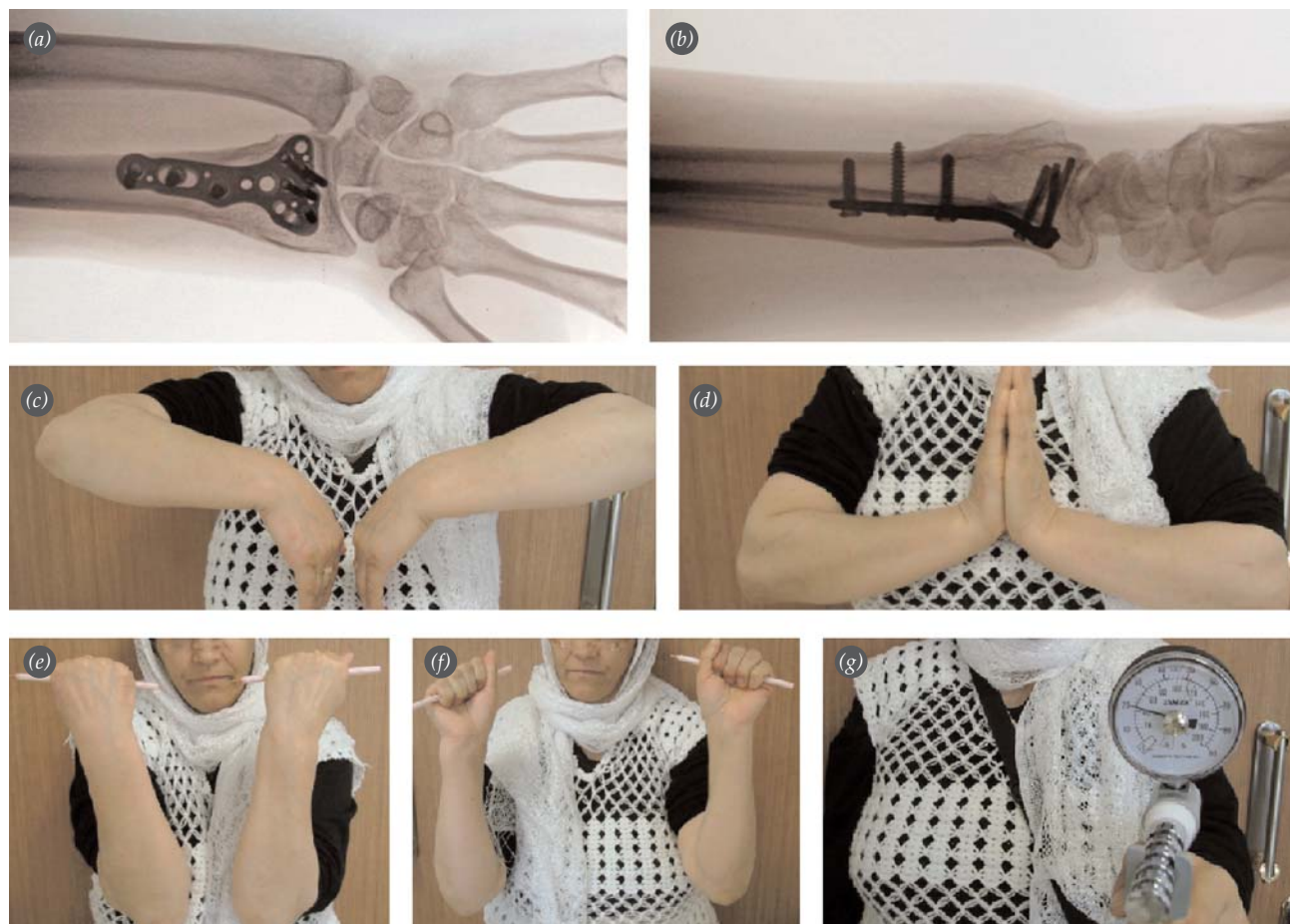
Fig. 3. **(a)** AP and **(b)** lateral radiographs, **(c-g)** functions from the final examination of the patient, whose radiographs are shown in Fig. 2. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Grade 2 radiological osteoarthritis was detected in 3 patients (17.6%) at the end of the follow-up period. One patient (5.8%) presented with complaints associated with tendinitis in the flexor pollicis longus. Surgical materials in these patients were removed in the sixth postoperative month.

Discussion

As well as being frequently seen, distal radius fractures remain on the agenda also due to improvements in surgical treatment.[27] The current consensus is that ideal treatment results can be obtained through an optimal anatomic correction.[3] However, malunions arising from delays in the required treatment as well as inappropriate and/or insufficient treatment attempts still restrict the daily routine of numerous adults.[28]

In the last 80 years, during which osteotomies have been used for the treatment of malunions of distal radius fractures, significant steps have been

Table 1. Patients' radiological data.

	Preoperative mean±SD	Postoperative mean±SD	Healthy side mean±SD	p value Student's t-test
Ulnar variance (+) (mm)	12.1±3.8	<1 mm±2	0	0.001
Radial tilt angle (°)	-27.4±9.7	3.4±2.3	2.2±2.5	0.14
Radial inclination angle (°)	18.4±6.3	22.5±2.1	25±2.1	0.01

Table 2. Patients' functional data.

	Preoperative mean±SD	Postoperative mean±SD	Healthy side mean±SD	p value Student's t-test
Wrist flexion (°)	42±12	51±14	62±9.8	0.01
Wrist extension (°)	58.8±7.3	55.9±10	82±8	>0.05
Forearm pronation (°)	60.5±3.5	78.5±10.5	87.3±4	0.001
Forearm supination (°)	58.2±10.4	78.2±10.5	87.3±4.3	0.001
Radial deviaton (°)	6±3	6.3±2	17±6	>0.05
Ulnar deviation (°)	16±2	21±4	22±3.5	0.01
Grip strength (kg)	17.5±6.9	24.4±8.2	29.3±8.2	0.01
Q-DASH (points)	26.5±8.9	5.7±8.3	0	0.001

taken in the surgical planning and techniques of the osteotomies.[2-4,12,14,17,24,29,30] However, there is still a debate on the decision between a volar or dorsal approach for the osteotomy, as well as the fixation technique of the osteotomy. According to this approach, osteotomies performed either on the dorsal or the volar surface, depending on the direction of the angulation, are fixed using conventional plates.[2-4,14] The method requires mechanical buttress; i.e. cortical spongious bone graft, as well as supplementing fixations, such as casting until complete healing. Furthermore, the fact that dorsal osteotomies are performed within a more limited surgical scope, as well as the problems encountered in the compliance of the fixation materials with the peripheral soft tissue, are among the key drawbacks of the method.[2,3,10,13] While the use of external fixators is advantageous in that less soft tissue damage is involved and progressive lengthening is possible, this method is not as preferred due to technical difficulties and occurring fixation losses.[2,31-35]

Treatment of distal radius fractures by fixed-angle volar plates is widely used.[27] The high biomechanical resistance of the plates, as well as the advantages entailed by the volar approach, are the key motives for the use of this method.[19,36] Correction of malunions, on the other hand, has a rather short history.[20-23] Encompassing a limited number of patients, these studies suggest that fixed-angle volar plates tend to contribute to the osteotomy treatment of dorsally angulated malunions in distal radius fractures.

A general evaluation of these studies yields the following three results: (1) Using fixed-angle plates provides a stable fixation and reduces the require-ment for the mechanical support through cortical cancellous graft. Hence, graft requirement could be reduced to spongious grafts or artificial grafts.[19-22] (2) Necessity of external fixation following the surgery is reduced, enabling early mobilization.[23] (3) The volar approach provides a wider surgical scope and facility in soft tissue covering.[21]

In this study of corrective osteotomies performed using fixed-angle plates, successful radiological and functional results were achieved, particularly in malunions presenting deformities in the articular surface of the radius. However, it was also found that functional loss and the development of degenerative arthritis could not be avoided in three patients (%17.6) with a history of intra-articular fracture (n=2; AO/ASIF Type C) and dynamic scapholunate dissociation (n=1). In one patient, we detected a case of flexor pollicis tendinitis, due to plate irritation, which is said to involve comparatively less significant complications in terms of soft tissue compliance when the material is removed at early stage.

A key limitation of this study is the wide-ranging age groups of the patients and the lack of a control group. The fact that the rotational deformities of the fractures were not included in the evaluation might be considered a further drawback.

In conclusion, due to their convenience and fixative durability, fixed-angle plates constitute a superior fixation option for the corrective osteotomy treatment in malunions of the dorsal angulated distal radius fractures. Thus, they may be an alternative to traditional corrective osteotomy techniques.

Conflicts of Interest: No conflicts declared.

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