Distal Radius Malunion

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Learning Objectives

Upon completion of this CME activity, the learner should achieve an understanding of:

- How malunions of the distal radius affect wrist biomechanics and can result in pain, limited motion, and functional limitations
- Optimal evaluation of a patient with malunion of a distal radius fracture
- Treatment options for malunion of the distal radius and associated complications

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Malunion remains the most common complication of nonsurgical treatment of fractures of the distal radius and represents a common clinical entity. Symptomatic treatment often involves corrective osteotomy. Surgical correction is a challenging problem with unpredictable clinical outcomes. Prevention of malunion of a distal radius fracture is the best course of action. With maintenance of volar cortical contact and the use of volar fixed-angle devices, bone grafting may not be necessary in certain cases of malunion correction. New technologies such as 3-dimensional modeling and computer-generated osteotomy guides are likely to have a positive impact on the outcomes of surgical treatment. *(J Hand Surg Am. 2020;45(5):433−442. Copyright © 2020 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words 3-Dimensional modeling, distal radius, fracture, malunion, osteotomy.

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Fractures of the distal end of the radius are common injuries, comprising 12% to 17% of all fractures.[1,2] Malunion of distal radius fractures (MDRF) is the most common complication of this injury and therefore a relatively common clinical entity. The incidence of MDRF appears to be greater when the fracture is treated with cast immobilization, with a historical incidence of approximately 24%.[3,4] Rates of malunion appear to be lower in fractures treated operatively.[4] With the advent of advanced surgical techniques, the incidence of MDRF has been calculated to be as low as 11%.[3] A meta-analysis of treatment outcomes of external compared with internal (plate and screw) fixation revealed an MDRF rate of about 4%.[5] Not all MDRF are symptomatic. Often, the degree of clinical severity does not correlate with bony deformity. However, when symptomatic, MDRF can result in considerable disability.

In a recent long-term follow-up study, Ali and colleagues[6] concluded that patients who sustain a distal radius fracture at age 18 to 65 years and develop malunion are more likely to have adverse clinical outcomes including activity limitation and pain. Compared with patients without malunion, those with malunion had notably worse Disabilities of the Arm, Shoulder, and Hand scores from baseline at 12 to 14 years, a difference that was clinically relevant. Despite the subjective discrepancy, there was no objective difference with regard to grip strength or final range of motion.

DEFINITION

Fracture displacement can be extra-articular or intra-articular. Extra-articular displacement can occur in any of the 3 planes. Displacement in the sagittal plane generally results in loss of the palmar tilt (dorsal angulation), although volar shear injuries can lead to an increase in the palmar tilt. In the coronal plane, displacement typically occurs in the form of loss of radial inclination and/or height. Rotational deformities in the axial plane can occur and are best appreciated with a computed tomography (CT) scan.[7]

A standard definition of MDRF has not been established, which makes it difficult to compare outcome studies. The American Academy of Orthopedic Surgeons has published clinical practice guidelines regarding operative management of distal radius fractures.[8] Postreduction dorsal tilt of greater than 10°, radial shortening of greater than 3 mm, or intra-articular displacement greater than 2 mm indicate the need for a discussion regarding the benefits of surgical fixation.

Worse outcomes have been reported in patients left to heal with this degree of initial deformity. Ali et al[6] defined MDRF as radial inclination of 15° or less, dorsal tilt of 10° or greater, and/or ulnar variance of 3 mm or greater. In contrast, Hasse et al[9] defined MDRF as radial inclination less than 10°, palmar or dorsal tilt greater than 20°, radial height less than 10 mm, intraarticular stepoff or gapping greater than 2 mm, and/or ulnar variance greater than 2 mm.

BIOMECHANICS

Malunion of distal radius fractures result in a fundamental change in the biomechanics of the wrist. Left untreated, this can lead to arthritis, pain, limited mobility, or dysfunction. Decreased radial inclination can result in a change in the direction of the flexor tendons, leading to a decreased mechanical advantage, and can cause hand weakness.[10] Loss of palmar tilt can lead to incongruity of the distal radial ulnar joint and tightening of the interosseous membrane, resulting in loss of forearm rotation.[11] This type of MDRF can go on to yield 2 types of carpal instability. The wrist will exhibit dorsal radial subluxation with maintenance of midcarpal alignment, or an adaptive midcarpal dorsal intercalated segment instability can develop (Fig. 1). The latter is usually more symptomatic and may be due to ligamentous laxity.[12] The loss of palmar tilt also limits flexion and supination, whereas increased palmar tilt decreases extension and pronation.[9,13] The effects at the distal radioulnar joint (DRUJ) can also be substantial. These may include an altered axis of rotation, reduced joint congruity, and limited forearm pronation and supination. Moreover, strain on the triangular fibrocartilage complex (TFCC) can occur and can lead to tearing.[11,14,15]

With respect to alterations in wrist kinematics, radial shortening is associated with a shift of force transfer from the radiocarpal to the ulnocarpal joint. As much as a 42% increase in the force borne by the ulnocarpal joint can be seen with a relative shortening of 2.5 cm of the radius.[16] As the shortening becomes more pronounced, the soft tissue stabilizers of the DRUJ become tighter, leading to loss of pronosupination and pain.[17] Using a cadaveric MDRF model, Bronstein and colleagues[15] found that 10 mm of loss of radial height led to substantial loss of supination (29%) and pronation (47%).

RADIOGRAPHIC EVALUATION

A standard wrist series should be performed on all patients suspected of an MDRF. The forearm should be held in neutral rotation and posteroanterior,

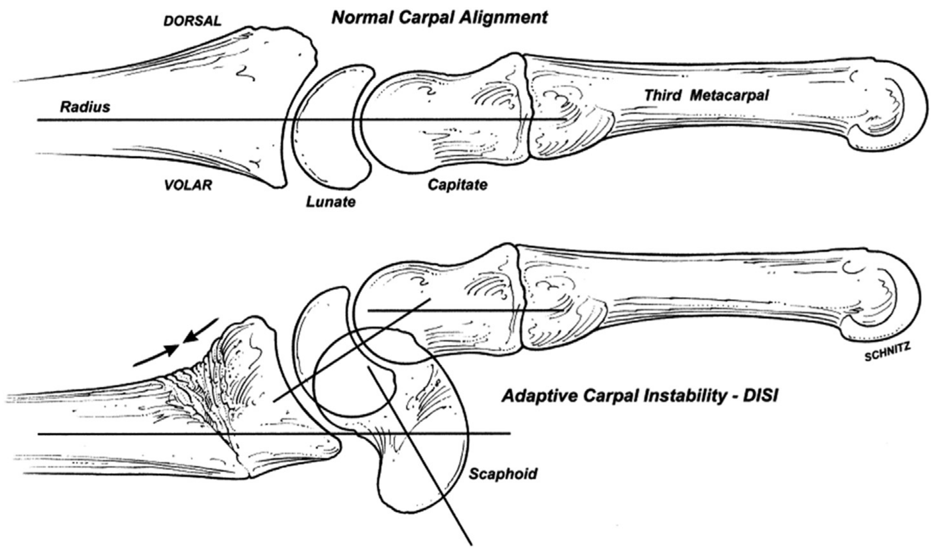

FIGURE 1: Scaphoid and capitate flexion noted with midcarpal instability. DISI, dorsal intercalated segment instability.

pronated oblique, and lateral views should be obtained. An anatomic, or tilted, lateral view can provide better visualization of the articular surface and lunate facet. The radiographic parameters of radial inclination, radial length, ulnar variance, and radial tilt can be calculated. Both a contralateral posteroanterior and lateral view are often helpful to determine the patient's normal anatomic parameters and ulnar variance. As mentioned, rotational deformity is hard to assess with 2 plane radiographs; if suspected, a CT scan may be beneficial. In addition, articular surface congruity and gapping are also often better visualized with CT imaging. Magnetic resonance imaging can help to elucidate the presence of soft tissue injuries such as intercarpal ligament and TFCC tears.

PREOPERATIVE CONSIDERATIONS AND TIMING

There are no absolute surgical indications for patients with MDRF. The degree of impairment and functional demands for each individual patient must be considered. Age, pain, weakness, function, and loss of mobility should be considered during shared decision-making with regard to the need for surgical intervention. For example, in older patients, anatomic deformity and function may not correlate directly. Young and Rayan[18] found that elderly, sedentary individuals with poor radiographic scores had an 88% satisfaction rate with their subjective clinical outcomes. The scores were calculated based on final dorsal angle, loss of radial length, and loss of radial inclination. Similarly, Diaz-Garcia et al[19] performed a systematic review of outcomes and complications with regard to distal radius fractures in patients aged greater than 60 years. The review demonstrated worse radiographic outcomes in patients treated with a cast. However, functional outcomes were no different from those of patients treated with a variety of surgical means.

The optimal timing to intervene for an MDRF remains unclear in cases in which surgery is indicated. Jupiter and Ring[20] found the results of early (defined as less than 14 weeks after injury) or late (greater than 14 weeks after injury) MRDF to be comparable. However grip strength averaged 42 kg after early, compared with 25 kg after the late reconstruction. The authors concluded that in patients who meet radiographic criteria predictive of functional limitation, early reconstruction is technically easier and the overall period of disability is shortened. Others recommend surgery as soon as the malunion is noted, given that within 1 to 2 months after injury, the fracture callus can be differentiated from cortical bone and anatomic alignment can be restored more reliably.[9]

DORSALLY ANGULATED MDRF

Dorsally angulated MDRF are most common. Classically, the bony malposition has been approached from the dorsal side in the form of an opening wedge osteotomy, with structural bone graft and plate osteosynthesis used to maintain alignment (Fig. 2A–D) The dorsal approach is between the second and fourth extensor compartments. This approach has the advantage of technical ease when performing an opening wedge osteotomy, as well as a

FIGURE 2: Preoperative and postoperative radiographs of a dorsal distal radius malunion fixed using a dorsal approach. **A** Preoperative posteroanterior view, **B** preoperative lateral view, **C** postoperative posteroanterior view, and **D** postoperative lateral view.

mechanical advantage of fixation on the tension side of the MDRF. Extensor tendon irritation or rupture has historically been considered a drawback to dorsal plating. Newer plating systems that use low-profile technology with an understanding of the extensor tendon anatomy have improved this approach and decreased the risk for hardware-related extensor tendon problems.

Tiren and Vos[21] reported on 11 patients successfully treated with an opening wedge osteotomy and a dorsal plate. All patients healed and no plates were removed.

The introduction of fixed-angle volar plates has made the volar approach a viable option for dorsally angulated MDRF. It can be accomplished by performing an opening wedge osteotomy through a

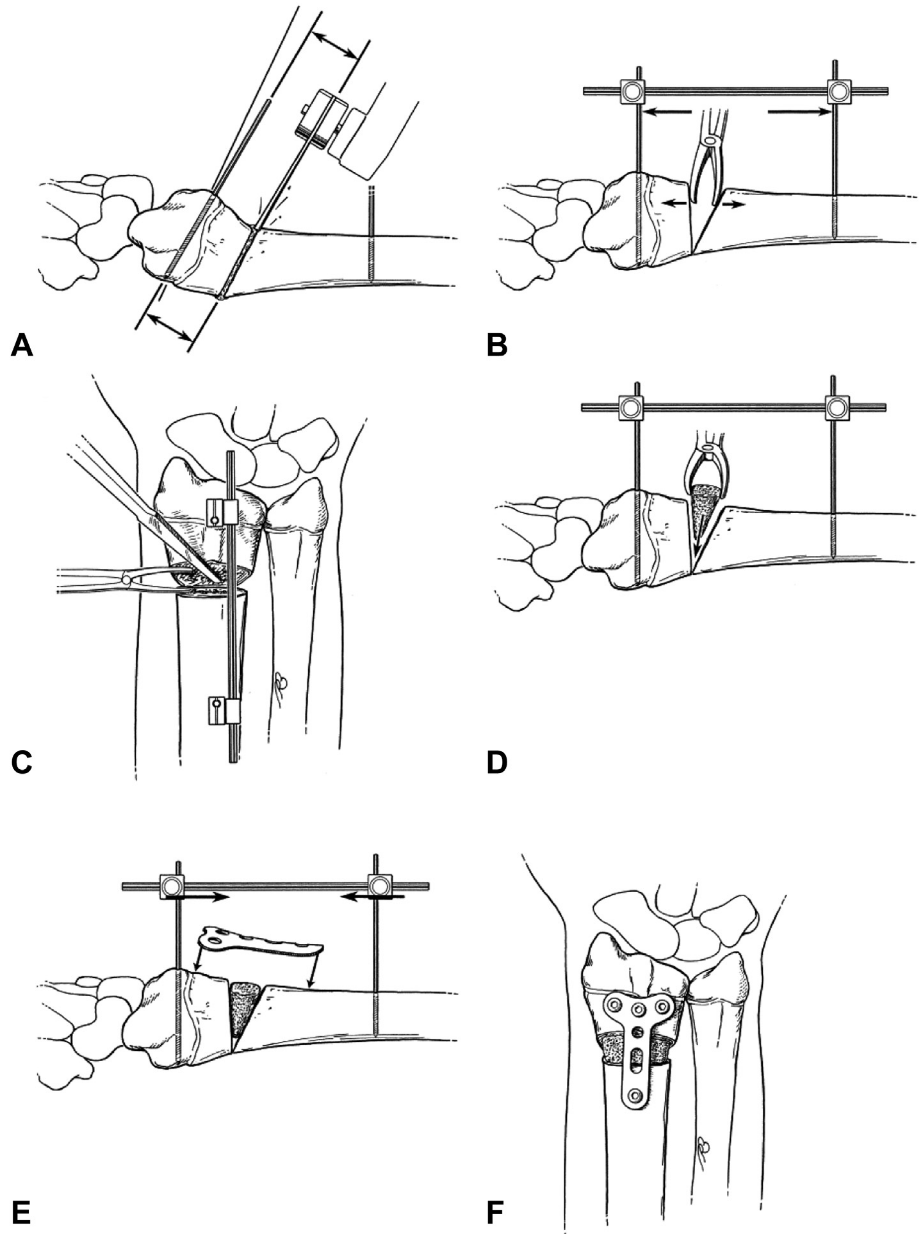

FIGURE 3: Distal radius osteotomy technique. **A** Saw-cut parallel to joint. **B, C** R-alignment of the radius to corrected position. **D** Placement of bone graft. **E** Placement of plate. **F** Final plate fixation.

standard or extended flexor carpi radialis or carpal tunnel approach (Fig. 3). Although volar plating has the theoretical advantage of decreasing tendon related complications, both flexor and extensor tendon issues can occur with these implants. In addition, the volar approach allows visual approximation of the volar cortex, which increases stability if properly realigned. Provided there is volar cortical contact, bone graft may not be required.[9,22,23] A potential risk exists of nonunion and possible construct failure with early motion owing to reliance on hardware to support the construct if structural bone graft is not used.[12] Distal fixation of the plate before the osteotomy can allow for more control than placement after the cut is made.[23] With this technique, the screws should be placed parallel to the articular surface. This also allows the lift maneuver, with the plate in place distally, to aid in reduction.[24] If increased visualization is needed to perform the cut after distal screw placement, the screws can be removed, leaving the tracts in place for plate and screw replacement directly after osteotomy.

FIGURE 4: Preoperative and postoperative radiographs of a volar distal radius malunion fixed using a volar approach. Note bone graft insertion. **A** Preoperative posteroanterior view, **B** preoperative lateral view, **C** postoperative posteroanterior view, and **D** postoperative lateral view.

Closing wedge osteotomies have also been described to treat dorsally angulated MDRF. These osteotomies offer the potential advantage of direct bone–bone contact and fixation with compression across the osteotomy site. Posner and Ambrose[25] described a biplanar closing wedge osteotomy to correct both tilt and radial inclination. Because of the increased ulnar variance after the osteotomy, the procedure was coupled with an ulnar head resection. Wada et al[26] compared closing with opening wedge osteotomies, with the closing wedge routinely coupled with an ulnar shortening. The authors found no complications related to the additional ulna shortening procedure. In addition, they found improvements in the restoration of ulnar variance, the extension-flexion arc of wrist motion, and the Mayo wrist score compared with the opening wedge osteotomies.

VOLARLY ANGULATED MDRF

When the deformity results from increased volar angulation, the optimal approach is an opening wedge osteotomy performed from the volar side. Sato et al[27] presented a series of 28 patients who underwent an osteotomy for treatment of a volar malunion. All patients had placement of an iliac crest structural graft and fixation with either standard or locked volar plates. All wrists united at the osteotomy site at an average of just

FIGURE 5: Preoperative and postoperative radiographs of a dorsal distal radius malunion fixed using a volar approach. Note volar cortical contact and absence of bone graft. **A** Preoperative posteroanterior view, **B** preoperative lateral view, **C** postoperative posteroanterior view, and **D** postoperative lateral view.

over 7 weeks, and supination improved to 80° from an average 16° before surgery (Fig. 4A–D).

INTRA-ARTICULAR MDRF

Treatment of MDRF with articular involvement is challenging and often requires advanced imaging such as CT to obtain an accurate delineation of the bony deformity. Ring and colleagues[28] found the results of treatment of MDRF with intra-articular and extra-articular osteotomies to be comparable. Osteotomy for MDRF can be performed safely through a dorsal or volar approach, can lead to improved function, and may limit the need for salvage procedures resulting from wrist degenerative changes. A dorsal capsulotomy can be performed and is ideal for patients with dorsal subluxation and articular MDRF in the sagittal plane. The volar approach should be used when volar subluxation is present.

The use of arthroscopy-aided osteotomy has been described with good results.[29,30] Piñal et al[29] employed CT scans to identify the major articular fragments, and then using arthroscopy, the fragments were identified with a probe. Osteotomes were then introduced into the joint space to mobilize the fragments under arthroscopic visualization. The fragments were then reduced and fixed with a volar fixed angle construct. The authors thought that time to fixation was important, because after 3 months the articular cartilage may be severely damaged and realignment would be of little benefit at that time point after injury. In a follow-up study,[30] the authors found good midterm clinical and radiologic outcomes in patients treated with this technique.

BONE GRAFTING

The void created with opening wedge osteotomies has traditionally been filled with autogenous bone graft (structural or nonstructural) or bone graft substitute. Ring et al[31] showed comparable results with nonstructural cancellous graft compared with iliac crest structural graft in patients treated with a dorsal opening wedge osteotomy and dorsal plating.

With the added strength of fixed-angle volar plates to secure the osteotomy site, bone graft substitutes have also been used. Luchetti[32] reported successful results with carbonated hydroxyapatite in the osteotomy gap, whereas Yasuda and colleagues[33] reported a healed osteotomy without fixation loss with calcium phosphate bone cement. Mahmoud et al[23] reported excellent results without grafting when using a volar locking plate. In 1 of 22 patients, a slight loss of reduction occurred that did not need to be revised. Ozer et al[22] found that as long as volar cortical contact was maintained, the use of bone allograft did not improve the final outcome. It was thought that the strength of the construct caused by the placement of the distal screws in healed cortical bone was sufficient to allow for appropriate healing (Fig. 5A–D).

ULNAR-SIDED WRIST PAIN

In patients with MDRF, ulnar wrist pain can be caused by ulnar abutment due to shortening of the radius and relative increase in ulnar length, instability of the DRUJ concomitant to soft tissue injury, TFCC tearing, posttraumatic arthritis of the DRUJ, or symptomatic ulnar styloid nonunion.[34] In those with ulnar abutment resulting from radial shortening, osteotomy of the distal radius may be sufficient treatment. Correction of radial malalignment in the sagittal plane, combined with lengthening of the articular segment at the metaphyseal osteotomy site, may restore more appropriate ulnar variance and relieve symptoms.[35] If realignment of the radius alone is insufficient, ulnar shortening osteotomy can be performed.

Tears of the TFCC are common in association with distal radius fracture, with a reported incidence of 40% to 80%.[34,36] Despite this high incidence, symptoms generally resolve without intervention. In cases of long-standing distal radius malunion with symptomatic tears, primary repair of the TFCC may not be feasible. Correction of the radius alignment may be sufficient to restore DRUJ stability. If not, wrist arthroscopy can be performed to confirm the presence of a peripheral TFCC tear and assess the suitability for primary repair. If the TFCC cannot be repaired primarily and the DRUJ remains unstable after correction of the radius, a ligamentous reconstruction is performed.[37]

Management of posttraumatic arthritis of the DRUJ in the setting of MDRF is challenging and requires an assessment of patient age, functional status, and demands. A variety of reconstructive options can be considered, including distal ulna resection, hemiresection arthroplasty, Sauve-Kapandji, and implant arthroplasty.[38] The procedure chosen depends on both the patient factors noted previously and surgeon preference and experience.

In patients with MDRF, an associated ulnar styloid nonunion does not typically need to be addressed unless symptomatic. The nonunion can be painful itself, and the irregular edges can result in tenosynovitis of the extensor carpi ulnaris. Treatment of ulnar styloid nonunion in association with MDRF depends on the size of the fragment and stability of the DRUJ. Small fragments associated with a stable DRUJ can be excised, with release of the extensor carpi ulnaris sheath and debridement of the tendon as needed. Larger fragments associated with DRUJ instability can be treated with direct repair using a headless compression screw or tension band wire, or with excision of the styloid fragment and repair of the TFCC back to the fovea.

USE OF 3-DIMENSIONAL GUIDES

The process of using a 3-dimensional (3D) guide involves obtaining a CT scan of a patient with a distal radius malunion and the normal unaffected side and converting these images into a stereolithography

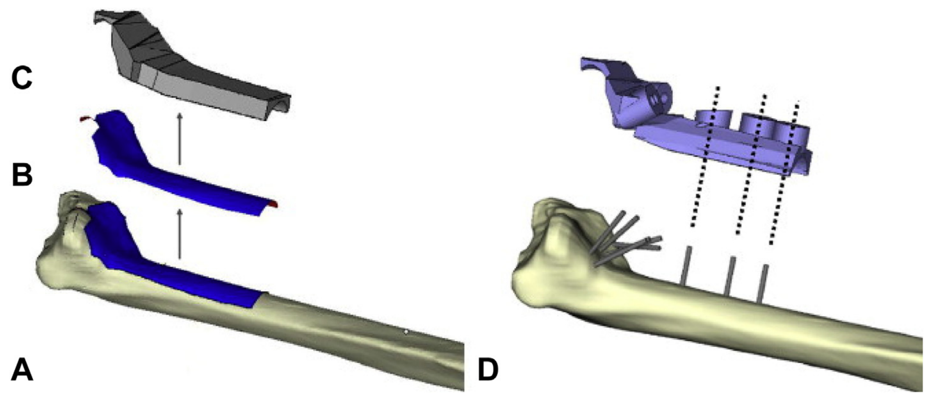

FIGURE 6: Creation of patient-specific instrument guide. **A** Selection of the registration surface. **B** Extracting the mirror image of the registration surface. **C** Integration of the mirror bone image into the patient-specific template. **D** Integration of the instrument guidance into the template with respect to the planned screw location.

(STL) file. A virtual osteotomy is then created on the digital malunited radius, and the volar surface manipulated into mimicking the contralateral normal side. A virtual plate is then applied to the surface of the osteotomized radius, and an STL file of cutting guide, including the holes for the plate, is then generated. The cutting guide STL file is then fed to a 3D printer, which will print a radiolucent plastic polymer cutting guide, sterilized and used during surgery (Fig. 6).

Kunz et al[39] described this technique and their experience in 9 patients with a distal radius malunion with an average follow-up of 7 months. The average deviation between the achieved and planned radial inclination in these patients was 1.8° (SD, 0.8°); for volar tilt, 1.9° (SD, 1.5°); and for ulnar variance, 0.9 mm (SD, 1.1 mm). The authors identified 2 complications: one infection and one case of posttraumatic arthrosis that required a wrist arthrodesis. Schweizer et al[40] described their experience with 6 symptomatic patients with intra-articular malunions of the distal radius treated with an outside-in corrective osteotomy. The osteotomies were guided by 3D-generated aiming guides, and all healed after 2 months. After 1 year, 4 patients were pain-free, one had mild pain, and one experienced moderate pain during heavy work. Wrist motion and grip strength were improved in all patients. No degenerative changes were found at the 1-year follow-up.

COMPLICATIONS

Haghverdian et al[41] reported complications of corrective osteotomies for extra-articular MDRF. The study group consisted of 60 patients who underwent the procedure over an 8-year period. A complication rate of almost 50% was observed. Infection, nonunion, loss of reduction, implant failure, nerve injury, tendon injury, and complex regional pain syndrome were recorded, 20% of which were tendon related. Tendon irritation and tendon rupture were both seen from dorsal and volar approaches. The complication rate was higher in patients who had a distraction-type osteotomy compared with those who had an osteotomy hinged on the volar cortex. Rivlin and colleagues[42] reported on 6 patients with extensor pollicis rupture after osteotomy and volar plate fixation for MDRF. Average time to tendon rupture was 10 weeks after surgery. Etiologic factors in the ruptures included dorsal callus formation in 4 patients, hardware prominence in one, and a dorsal osteophyte in the last patient.

CONCLUSION

Malunion of distal radius fractures remains the most common complication of nonsurgical treatment of fractures of the distal radius and represents a common clinical entity. Surgical correction is a challenging problem with unpredictable clinical outcomes. Prevention of MDRF is the best course of action. Volar fixed-angle devices, bone graft technology, and 3D modeling and computer-generated osteotomy guides are promising new technologies that are likely to have a positive impact on the outcomes of surgical treatment of this vexing clinical problem.

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