Wrist Fractures and Osteoporosis

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KEYWORDS

• Wrist fracture • Osteoporosis • Outcomes • Treatment options • Elderly patients

KEY POINTS

- Osteoporosis is a predominant factor for low-energy distal radial fractures in the elderly.
- Distal radial fractures may be the first opportunity to evaluate and treat osteoporosis to reduce the risk of future fragility fractures.
- Treatment may involve pharmacotherapy, closed reduction and splinting or casting, external fixation, or open reduction and internal fixation.
- Published evidence supports favorable functional outcomes, regardless of the presence of osteoporosis, after volar plate fixation of distal radial fragility fractures.

Although both conservative management and surgical management have been reported to be successful, current evidence and the most recent American Academy of Orthopaedic Surgeons (AAOS) clinical guidelines comparing conservative and surgical treatment of distal radial fragility fractures are inconclusive. Each treatment method has its advantages: volar locking plate fixation allows earlier mobilization than casting, with better functional outcomes; Kirschner (K)-wire fixation can minimize the risk associated with open surgery; intramedullary fixation increases fixation strength, prevents tendon irritation, and speeds return to activity; and dorsal distraction plating allows early weight-bearing across the wrist. Treatment must be individualized based on fracture pattern, patient age, activity level, and osteoporosis severity.

Fractures caused by a low-energy mechanism in patients with poor bone quality and osteoporosis (fragility fractures) are a major health concern for the elderly population, with more than 1.5 million injuries occurring each year in the United States.[1] Osteoporosis is defined as a bone mineral density (BMD) of less than 2.5 SDs of peak bone mass below a healthy gender-matched young adult. In individuals with osteoporosis, a fall from standing can result in distal radial, proximal humeral, hip, and pelvic fractures. Fragility fractures are associated with significant morbidity and mortality and can cause disability that can ultimately lead to a loss of independence. The 1-year mortality after a hip fracture is 20% in the elderly population, and only 50% of hip fracture patients return to their previous level of function.[2,3] Although isolated distal radial fractures can cause difficulty in performing activities of daily living, they do not seem associated with increased mortality.[4] One study, however, found that women from 60 years to 79 years of age who had sustained a fracture of the distal radius or proximal humerus had a relative risk of sustaining a future hip fracture of 1.9, with the highest risk within the first year after a fracture.[5] A prospective cohort study followed 113 patients for 4 years after sustaining a distal radial fracture and found that 24% experienced a subsequent fall and 19% experienced a subsequent fracture during that time.[6,7] A distal radial fracture seems a fortunate outcome in comparison to a hip fracture in a fall, and it may serve as an early indicator for future fragility fractures and morbidity.

Osteoporosis is a predominant factor for low-energy distal radial fractures in the elderly and should not be overlooked. Disruption of the

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balance between bone formation and resorption leads to an age-related decrease in bone mass and eventual osteoporosis. Decreased activity, hormonal changes, and vitamin D and calcium deficiency are factors that contribute to osteoporosis in the elderly. Patients with distal radial fractures have been found to have an increased level of bone turnover markers of formation and resorption.[1] Rozental and colleagues suggested that these turnover markers may be helpful in predicting future fragility fractures in premenopausal women. In a comparison of patients who were and were not receiving hormonal treatment, the risk of a distal radial fracture was reduced by 33% in those who had hormonal treatment for 10 years and by 63% in those who used them for 15 years.[8] The study also showed that long-term hormonal therapy protected bone loss and reduced the frequency of wrist fractures. Hormonal therapy of less than 5 years did not have a long-term protective effect, but the study was under-powered to confirm this result.

DEMOGRAPHICS OF AND RISK FACTORS FOR DISTAL RADIAL FRACTURES

Distal radial fractures account for up to 18% of all fractures in patients over 65 years of age.[9] Risk factors include female gender, obesity, frequent falls, white race, and diagnosis of osteoporosis.[10] The prevalence of osteoporosis in patients with distal radial fractures is high compared with matched control subjects, regardless of gender.[11] A study from Canada demonstrated that all participants older than 65 years of age were at moderate or high risk for an osteoporotic fracture when using the fracture risk assessment and Canadian Association of Radiologists–Osteoporosis Canada risk assessment tools.[12] The investigators recommended that these patients should be considered for pharmacotherapy.

Distal radial fractures often are the first clinical sign of osteoporosis because they tend to occur in younger patients compared with patients who sustain hip fractures. Studies have shown that patients who sustain distal radial fractures are more likely to be fully cognizant and independent, with effective neuromuscular control and walking speeds, because they are able to reach out and break their fall.[13] Hip and proximal humeral fractures, however, tend to occur in less functional patients who are unable to break their fall, resulting in impact on the shoulder or hip. Current evidence suggests that osteoporosis and poor BMD correlate with increasing severity of the distal radial fractures, with more severe fractures leading to early and late displacement, late carpal malalignment, and malunion.[14]

DIAGNOSIS

Distal radial fractures also may be the first opportunity to evaluate and treat osteoporosis to reduce the risk of future fragility fractures.[1,15,16] A prospective, randomized controlled study showed that initiation of an osteoporosis workup by an orthopedic surgeon results in a statistically significant increase in treatment compared with referral to a primary care physician.[1] Treatment of osteoporosis should be initiated if it is a new diagnosis.

Because distal radial fractures may be the initial presentation of osteoporosis, the ability to diagnose osteoporosis accurately using hand and wrist radiographs would be helpful in expediting referral and initiating treatment; however, 1 study found that digital hand radiographs had poor accuracy compared with dual-energy x-ray absorptiometry (DEXA) scans and had only fair agreement in diagnosing osteoporosis.[17] Another study demonstrated that the second metacarpal cortical percentage calculated from standard radiographs of the hand and wrist may have a role in accurately screening for osteopenia and osteoporosis.[18] Hounsfield unit measurements from distal radial CT scans also have been reported to identify patients who require further metabolic bone disease workup, referral, and initiation of osteoporosis treatment[19]; however, it is difficult to justify the higher radiation dose associated with CT imaging and, therefore, it may not be practical in the clinical setting. At the least, a simple observation of thinned distal radial cortices on plain radiographs should prompt further evaluation with DEXA and medical management, given that the average radial bicortical thickness statistically correlates with femoral bone density.[20]

TREATMENT

Medical Treatment

Medical treatment can include vitamin D, calcium, bisphosphonate medications, and recombinant human parathyroid hormone (PTH), also known as teriparatide.

The effect of bisphosphonates on healing after distal radial fractures has been investigated because they often are used as the initial treatment of osteoporosis by inhibiting osteoclasts and decreasing bone resorption. One study found that early initiation of bisphosphonate treatment did not affect fracture healing or clinical outcomes of distal radial fractures.[21] In another study, patients receiving bisphosphonates at the time of sustaining a distal radial fracture had clinical outcomes similar to patients who were not receiving treatment.[22]

Bisphosphonates seem safe and can be continued throughout nonsurgical treatment of distal radial fractures without detrimental effects on healing or function.

Teriparatide, a recombinant form of PTH, contains the active terminal portion (1–34 amino residues) and recently has been shown to increase skeletal mass and bone strength and augment healing.[23–25] Teriparatide was Food and Drug Administration approved in 2002 for treatment of postmenopausal women and osteoporotic men who are at high risk of fracture. Teriparatide is administered daily by subcutaneous injection; treatment duration of more than 2 years is not recommended during a patient's lifetime. The daily dosing schedule simulates pulsatile PTH signaling, which leads to increased bone formation. In contrast, continuous infusion or constant PTH signaling would lead to bone resorption. Complications of teriparatide treatment include transient hypercalcemia, nausea, and headaches. It is contraindicated in patients with Paget disease and prior high radiation exposure because of concerns for a possible increased risk of osteosarcoma.[26] The true effectiveness of this medication in reducing fragility fracture is only beginning to be studied. A recent retrospective observational analysis found teriparatide most effective at 6 months after initiation of treatment after any fragility fracture, with a relative risk reduction still present at 2 years after discontinuation of treatment.[27]

Closed Reduction and Casting/Splinting

Nonoperative treatment can be considered for distal radial fragility fractures that are minimally displaced or are extra-articular and in which acceptable radiographic alignment can be maintained with immobilization after closed reduction. Fractures in patients who may be unfit for surgery, especially those with low functional demands, also may be treated conservatively. The benefits of closed treatment include minimizing the risk of infection, anesthesia, and surgical complications. Short-arm cast or splint immobilization often is required for 6 weeks to 8 weeks, with frequent follow-up to monitor for late displacement, angulation, or subsidence that can occur as a result of poor bone quality. One study reported that closed treatment of distal radial fractures in patients with osteoporosis increases the risk of dorsal and radial tilt resulting in malunion.[28] Calcaneal BMD measurements may have some benefit in identifying patients at risk for severe malunion, but current evidence does not suggest a correlation between functional outcomes and BMD for conservatively treated distal radial fractures.[28,29] This may be because maintenance of anatomic alignment and reduction has not been shown to be essential for obtaining acceptable functional outcomes. Gutiérrez-Monclus and colleagues[30] found no significant correlation between acceptable alignment (according to radiological parameters) and short-term or medium-term functional outcomes in patients older than 60 with extra-articular distal radial fractures treated conservatively.

Operative Treatment

Current evidence and the most recent AAOS clinical guidelines comparing conservative and surgical treatment of distal radial fragility fractures are inconclusive and are limited by the use of a variety of functional outcome scores and an inability to compare a uniform fracture characteristic among all studies. A systematic review and meta-analysis did not demonstrate superior clinical outcomes after operative treatment in elderly patients with distal radial fractures[31]; however, the review did demonstrate that operative treatment can lead to better radiographic outcomes and grip strength compared with nonoperative treatment, despite an increased risk of complications. Another systematic review showed similar functional outcomes, using the Disabilities of the Arm, Shoulder and Hand (DASH) score, between operative and nonoperative treatment of distal radial fractures in the elderly.[32] A 2017 study comparing open reduction and internal fixation (ORIF) with volar locking plates to nonoperative treatment showed no difference in overall functional outcomes (DASH and Mayo wrist scores) at 12 months after injury.[33] The investigators did caution that longer follow-up is needed to determine if posttraumatic arthritis would negatively affect functional outcome scores. In contrast to this study, a 2018 randomized prospective study found that fixation led to better outcomes than conservative treatment in elderly patients with intra-articular distal radial fractures.[34] Finally, to minimize the risk associated with the use of anesthesia in the elderly population, wide-awake local anesthesia, no tourniquet, also has been described for treatment of distal radial fractures in patients with extensive comorbidities.[35] Well-designed, high level of evidence studies will help determine if there is any true benefit of surgical fixation considering the risks associated with anesthesia and surgery.

Kirschner wire fixation

K-wire fixation is a cost-effective method for stabilizing distal radial fractures. Percutaneous placement can minimize the risks associated with open surgery, but loss of fixation, subsidence, pin loosening, and infection can occur. In addition, K-wire removal often is recommended after fracture healing and can sometimes require a second procedure in the operating room. K-wire fixation may not be effective for fractures with comminution and significant shortening. One study demonstrated that K-wire fixation was effective in maintaining sagittal plane angulation after reduction but not radial length in extra-articular fragility fractures.[36] The best predictor of radial length was the radial length before fracture reduction, and the investigators recommended that K-wire fixation should not be used if radial shortening is visible on injury radiographs. Another study compared volar locking plate fixation to K-wire fixation and found that patients treated with volar locking plates had better functional outcomes in the early postoperative period and a reduced risk of developing complex regional pain syndrome.[37] The study also compared K-wire fixation to nonsurgical treatment and found a significantly higher percentage of excellent and good results, indicating that there may be a role for K-wire fixation over closed treatment.

Volar plating

The widespread use of volar locking plates for distal radial fractures is likely due to their ability to provide a strong biomechanical construct while using the familiar volar approach for most distal radial injury patterns, even in the presence of dorsal angulation and poor bone quality (**Fig. 1**).[34,38–40] Many studies have demonstrated the biomechanical strength of volar locking plates, with a recent study providing further evidence that osteoporosis and cortical thickness of the distal radius does not affect clinical outcomes after volar locking plate fixation.[39] Another benefit of volar locking plate fixation is earlier mobilization compared with cast treatment, with recent evidence suggesting that postoperative splinting and immobilization after volar locking plate fixation is unnecessary and even detrimental.[41] Flexion/extension, pronation/supination, pain and *Quick*DASH scores at 3 months after surgery were all better in the group without postoperative splinting.

Early studies questioned the capabilities of volar locking plates to provide improved functional outcomes in patients with osteoporosis. One study suggested that osteoporosis had a negative impact on functional outcomes in women treated with ORIF compared with women with osteopenia.[42] Another study suggested that osteoporosis had a negative effect on the range of motion of the wrist.[43] They found that activities of daily living were significantly restricted after plate osteosynthesis, despite finding no radiological difference between the osteoporotic and nonosteoporotic patients. In retrospect, the mean ages in the 2 groups were 56.5 years for the osteoporotic group compared with 37.1 years for the nonosteoporotic group, and this may have confounded their results. More recent studies have provided evidence supporting favorable functional outcomes, regardless of the presence of osteoporosis, after volar plate fixation of distal radial fragility fractures.[37,44,45] Several studies have shown that elderly patients, even those older than 70 years of age, treated with volar locking plate fixation have improved Mayo wrist scores and grip strength with no residual pain in most patients.[40,46] Another study showed that, despite loss of reduction for volar tilt and radial height within the first 4 months, the volar locking plate maintained intra-articular fracture stability with radiographic parameters within a functional range over time in most elderly patients (mean follow-up of 31 months).[45] There also is no clear association between BMD status and the risk of mechanical failure after volar locking plate fixation.[47]

Complications of volar plating

The complications associated with solar locking plates should be strongly considered (and discussed with patients preoperatively) when choosing surgical fixation.[2] One study reported an overall complication rate of 14.6% at 3.2-year follow-up of 576 patients who had volar plating.[48] Complications included carpal tunnel syndrome or change in sensibility, tendon irritation and rupture, deep infection, and complex regional pain syndrome. Another study reported a 7.5% complication rate in 824 patients. Application of the volar locking plate distal to the watershed line can increase the risk of flexor tendon irritation and rupture. Dorsal screw prominence also can lead to extensor tendon irritation or rupture.[49] A unique complication associated with the use of the volar locking plate is the occurrence of a longitudinal fracture line beneath the plate and extending proximally.[50,51]

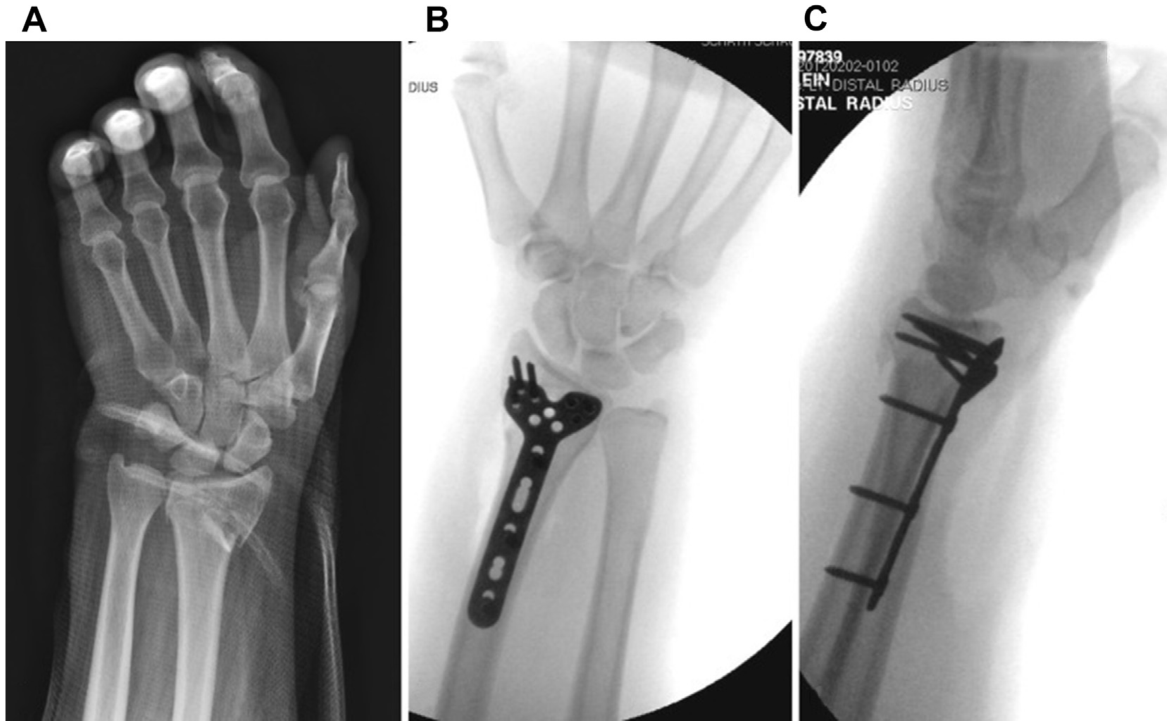

Fig. 1. (*A–C*) Volar plate fixation of a fracture of the distal radius. (*From* Perez EA. Fractures of the shoulder, arm, and forearm. In: Azar FM, Beaty JH, Canale ST, editors. Campbell's operative orthopaedics. 13th edition. Philadelphia: Elsevier; 2017. p. 2999; with permission.)

The fracture likely occurs after reduction of the plate to the bone with a nonlocking screw, followed by over-penetration of the near cortex by the conical head of a diaphyseal locking screw. This screw acts as a wedge, causing the longitudinal fracture line. Elderly patients may be more at risk because the near cortex may become more brittle with age and bone thinning.

Dorsal Plating

The use of dorsal plate fixation has decreased with increasing evidence supporting the ability of volar locking plate to provide stability for dorsally angulated distal radial fractures, familiarity of the volar approach to the distal radius, and early high rate of complications reported with dorsal plate fixation. There are certain fracture patterns, however, that may benefit from dorsal fixation and/or a dorsal approach for visualization and reduction. These patterns include dorsal shear fractures (dorsal Barton), die-punch fracture, and patterns in which indirect reduction cannot be obtained from a volar approach.[52] The most notable complication associated with dorsal plate fixation is attritional extensor tendon irritation and rupture. Most of these complications occurred in older-generation plates, with more recent studies reporting that favorable outcomes and minimal complications occur with newer-generation implants.[53–56] Newer dorsal implants can minimize attritional wear by having precontoured plates available in a variety of sizes with polished surfaces, tapered edges, and low-profile screw heads.[57] Similar to the volar locking plate, dorsal locking plates are available to improve fixation in osteoporotic bone and to allow early range of motion.

Fragment-specific Fixation

Fracture-specific fixation allows for a systematic approach for treatment of complex distal radial fractures by stabilizing each fragment individually to restore the radial and intermediate columns of the distal radius.[58] Various implants are designed to provide anatomic rigid fixation to the radial styloid, volar, and dorsal ulnar corner and articular shear fragments. Multiple incisions are often needed to obtain proper exposure if multiple fragments require fixation. Biomechanical studies demonstrate that applying an implant in more than 1 plane increases rigidity and the use of two 2.0-mm implants with a 50° to 90° offset angle between them in the axial plane provides stronger fixation than a single 3.5-mm plate.[59,60] A biomechanical cadaver study found significantly less linear displacement and angulation at the osteotomy site in the fragment-specific fixation group compared with volar locking plate at loads expected to be encountered during postoperative rehabilitation.[61] Angulation at the osteotomy site was significantly less, however, in the volar locking plate group at higher loads. Fragment-specific fixation can be used in conjunction with volar locking plate to provide biomechanically superior strength and stability if a stronger construct is required. Fracture-specific implants have the ability to stabilize volar rim fragments[62] and the volar ulnar corner while minimizing the risk for flexor tendon damage or rupture, a complication that can result from implant prominence due to restrictions of a larger fixed-angle device.[63] Stabilizing this fragment is essential to avoid the catastrophic complication of volar subluxation of the carpus.[64]

Outcomes of Fragment-specific Fixation

Benson and colleagues[65] reported good to excellent results with range of motion, grip strength, radiographic alignment and satisfaction scores in patients with intra-articular distal radius fractures treated with fragment-specific fixation. A randomized controlled study compared fragment-specific fixation to volar locking plates and demonstrated good results in both groups and similar patient-reported outcomes.[66] There was, however, a significantly higher complication rate for the fragment-specific group. There is clearly a role for fracture-specific implants because they allow versatility and the ability to stabilize fractures that cannot be adequately treated with a single implant.[67–69]

Percutaneous Endomedullary Internal Fixation

Solarino and colleagues[70] investigated the use of the Epibloc system, a percutaneous endomedullary internal fixation system developed in Italy, in low-functioning patients with multiple medical comorbidities who would not respond well to the stress of extensive surgery. They compared the Epibloc system to volar locked plating and reported that volar locked plating was associated with better outcomes in both intra-articular and extra-articular distal radial fractures; however, in both the plating and Epibloc groups, grip strength mean values were greater than the minimal level needed to be considered a functional wrist. As a result, these investigators advocated the use of the Epibloc system in patients in whom minimally invasive surgery is preferred.

Intramedullary Fixation

Intramedullary fixation can be used selectively to treat dorsally angulated extra-articular and simple intra-articular distal radial fractures. The implant is inserted through the radial styloid, between the first and second dorsal compartments, using a limited dorsal radial incision (Fig. 2). Intramedullary fixation should be

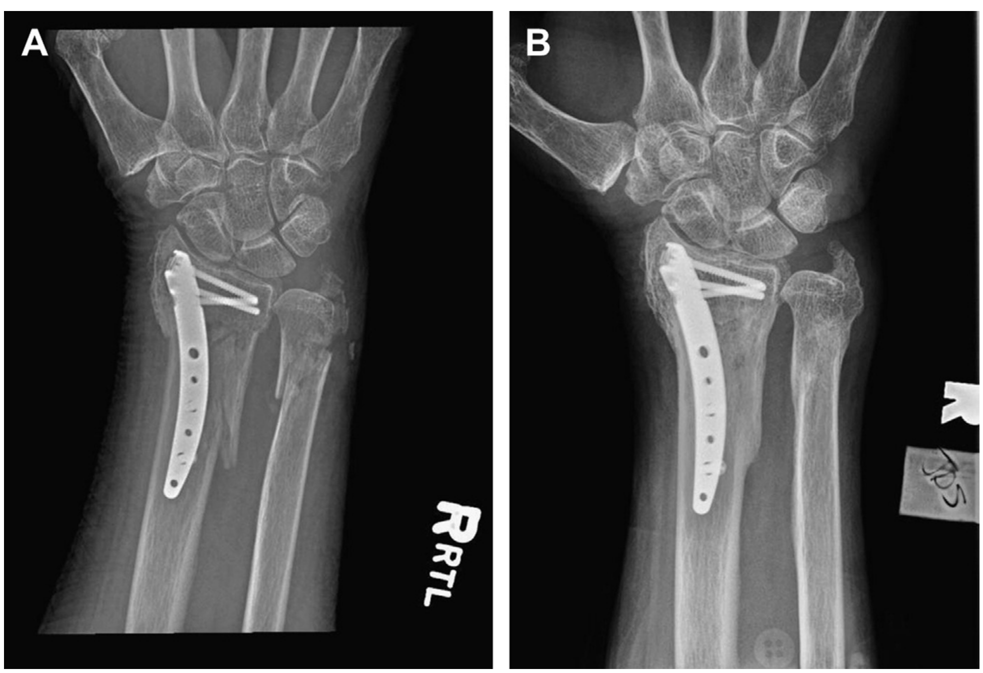

Fig. 2. (*A*) Three-week follow-up of a distal radial fracture with metaphyseal extension treated with an intramedullary nail. (*B*) Six-month follow-up radiograph shows union of the fracture. (*From* Harreld K, Li Z. Intramedullary fixation of distal radius fractures. Hand Clin 2010;26(3):367; with permission.)

Fig. 3. Immediate postoperative (*A*) posteroanterior and (*B*) lateral radiographs demonstrate placement of a 14-hole, small-fragment locking compression plate, with 3 bicortical screws in the radial diaphysis and 3 in the third metacarpal. (*From* Richard MJ, Katolik LI, Hanel DP, et al. Distraction plating for the treatment of highly comminuted distal radius fractures in elderly patients. J Hand Surg Am 2012;37(5):951; with permission.)

avoided if the fracture cannot be preliminarily reduced by closed or percutaneous means because the implant cannot facilitate reduction, unlike a volar locking plate.[71] Marginal rim or sagittal shear intra-articular fracture fragments also cannot be adequately treated using an intramedullary implant. Advantages of intramedullary fixation include minimizing surgical exposure, preventing tendon irritation, and speeding return to activity.[72] Biomechanically, intramedullary fixation provides enough stability to allow for early postoperative range of motion through a load sharing, fixed-angle device.[73] A prospective case series demonstrated at least 90% return of wrist flexion, extension, ulnar deviation, radial deviation, pronation, supination, and grip strength compared with the contralateral side after intramedullary fixation in these fractures.[74] When using the modified Mayo wrist score, there were 20 excellent and 9 good results. The study did not compare intramedullary fixation to other treatment options, such as the volar locking plate. Complications reported after intramedullary fixation include carpal tunnel syndrome, superficial radial nerve injury, screw loosening, and a proud screw tip that contacted the ulnar head.[72] Radial shortening with excessive volar tilt occurred in 2 distal radial fractures in the Nishiwaki and colleagues[74] study. The intramedullary construct can provide sufficient stability to prevent dorsal displacement[73,75]; however, it may be less effective in preventing volar displacement. Careful attention should be made to select an implant of appropriate size in patients with osteoporosis and a large intramedullary canal.[76]

Spanning Internal and External Fixation

Dorsal distraction plating (functioning as an internal fixator) has been described for treatment of highly comminuted intra-articular distal radial fractures and fractures in multiply injured patients. The technique varies in the literature, with some investigators fixing the plate to the second metacarpal (through the second dorsal compartment) and others to the third metacarpal (through the fourth dorsal compartment).[77] Dorsal distraction plating allows early weight bearing by spanning the radiocarpal joint, enabling a multiply injured patient to sit up, transfer, and ambulate without restriction (Fig. 3).[78] The implant usually is removed after 3 months, when fracture healing is complete. Hanel and colleagues[79] reported minor and major complication rates of 4.6% and 8.5%, respectively. Because plate fracture and screw failure occurred when a 2.7-mm plate and 2.4-mm screws were used, they recommended the use of a larger 3.5-mm plate and 2.7-mm screws. Other reported complications of dorsal plate distraction include finger stiffness requiring tenolysis, extensor tendon irritation, metacarpal fractures through a distal screw hole prior to plate removal, and 1 reported case of extensor tendon rupture after the patient did not return for planned plate removal.[79–82] The metacarpal fractures were treated closed and were healed by the time of plate removal. The current evidence for dorsal distraction plating is limited to retrospective case series, and there are no data comparing the technique to external fixation or plate fixation. Multiply injured patients often are younger than patients with osteoporotic distal radial fractures, with most dorsal distraction plating studies reporting an average age in the early fifties.[79] Evidence supporting the use of dorsal distraction plating for highly comminuted fractures in the elderly is yet to be determined.

Indications for external fixation are similar to dorsal distraction plating, with the notable additional indications of grossly contaminated wounds and significant soft tissue injury. External fixation avoids placement of an incision in these areas and can be used as temporary or definitive treatment. Evidence supporting the use of external fixators specifically for osteoporotic distal radial fragility fractures also is currently limited.

Wrist Hemiarthroplasty

Primary wrist hemiarthroplasty for irreparable distal radial fractures has been described in independent elderly patients (more than 65 years of age), with acceptable outcomes at 30-month follow-up.[78] A cement-less stemmed implant is instrumented into the distal radius with careful attention made to restore distal radial length. Irreparable fractures have been defined as any fracture that displays a combination of the criteria: AO type C complete intra-articular fracture, high extra-articular and intra-articular displacement scores, main fracture line distal to the watershed line, impaction, and circumferential comminution.[78] The main advantage of wrist hemiarthroplasty is early mobilization without the usual restrictions associated with concerns for implant failure and fracture healing. Future studies are required to determine long-term outcomes, implant survival rates, and late complications to fully validate this treatment option.

SUMMARY

Osteoporosis is a significant risk factor for distal radial fragility fractures in elderly patients. Good functional outcomes can be obtained with nonsurgical and surgical fixation methods, depending on the fracture configuration and patient age, comorbidities, activity level, and osteoporosis severity.

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