Evaluation and treatment of osteoporotic distal radius fracture in the elderly patient

Eric M. Padegimas · Daniel A. Osei

Published online: 18 January 2013
© Springer Science+Business Media New York 2013

Abstract Distal radius fractures are an increasingly prevalent upper extremity injury, especially among elderly patients. While treatment guidelines for the acute bony injury have been well documented, treatment of the underlying metabolic bone disease has been less commonly discussed in the orthopedic literature. Distal radius fractures in the elderly patient should be considered a sentinel event for injuries associated with greater morbidity and mortality, such as hip fracture. Management of fracture-related factors, such as osteoporosis and increased fall risk following a distal radius fracture, may prevent the mortality and morbidity of future injuries. This review highlights both the fracture-specific and medical goals of treatment in the elderly patient with a distal radius fracture.

Keywords Distal radius fracture · Osteoporosis · Wrist · Geriatric · Vitamin D · Review

Introduction

Distal radius fracture (DRF) is the most common upper extremity fracture affecting elderly patients [63••]. With 640,000 reported DRFs in the United States in 2001, the health and economic burden is substantial [1, 2••]. DRFs contribute significantly to the estimated \$1.1 billion cost of osteoporotic fractures in the Medicare population [58••, 64]. For unknown reasons, the incidence of these fractures has been on the rise both in the U.S. and globally [2••, 3, 4••, 5, 6]. Furthermore, the increase in incidence has disproportionately affected patients 65 years old and older [7]. Within this population, DRFs account for 18 % of all fractures [8]. This

injury is especially prominent in the active elderly, since the common mechanism of fracture is a standing level fall (SLF) onto a dorsally outstretched hand. As life expectancy increases and as people continue to stay active later in life, geriatric DRF has become an increasingly important clinical problem [9–11].

The aim of this review is to explore the risk factors of DRFs, as well as how they may be interpreted as a sentinel event for other more morbid fragility fractures, such as hip or vertebral fractures. The significance of this evaluation is two-fold: determination of measures that may be taken to prevent DRFs prophylactically and evaluation of the DRF as a sentinel event, in order to prevent occurrence of more morbid injuries.

Epidemiology/risk factors

Patient age and gender are the two best predictors of DRF. The incidence in men remains low, relative to women, but becomes as high as 281 per 100,000 person-years in the 8th decade of life [12••]. The incidence in men then further increases to 466 per 100,000 in the over-80-year-old population. Women show a significant increase in incidence after age 50 (from 169/100,000 between ages 40 and 49 to 541/100,000 between ages 50 and 59). As for men, the incidence in women continues to increase with age to a peak of 1,107/100,000 over the age of 80 years. The disproportionately high incidence in elderly women has been corroborated by a number of studies [10, 13, 14]. There are many factors that contribute to this increased risk in the elderly, especially elderly women. Architectural and qualitative changes in bone and decreased bone mineral density (BMD) in conjunction with an aging population that has become increasingly active explain this epidemiological pattern. Osteoporosis, defined as a BMD of -2.5 standard deviations or less of peak bone mass (average of healthy, gender-matched, young adults) and osteopenia defined as a BMD of

E. M. Padegimas · D. A. Osei (✉)
Department of Orthopedic Surgery, Washington University School
of Medicine, Campus Box 8233, 660 South Euclid Avenue,
St. Louis, MO 63110, USA
e-mail: oseid@wustl.edu

–1.0 to –2.5 standard deviations of peak bone mass (average of healthy, gender-matched, young adults) are well-known risk factors of DRF in elderly women [15, 16, 17•, 18•, 19•, 20•]. Furthermore, decreased BMD has been found to be predictive of severity of DRF [21].

In addition to BMD, the correlation between hypovitaminosis D and DRFs has recently been explored. The role of vitamin D in bone mineralization, growth, and remodeling is well-known and documented [22–24]. In a study examining 37 male patients from 30 to 75 years old with distal forearm fractures, 49 % of these had vitamin D insufficiency, defined as serum levels between 20 and 30 ng/mL, or deficiency, defined as serum levels less than 20 ng/mL [25]. Jang et al. looked at 104 postmenopausal women treated surgically for DRF, along with 107 age-matched controls. In the group that sustained DRFs, 19 were vitamin D deficient, and 27 were vitamin D insufficient, while in the control group, only 2 were deficient, with 12 being insufficient ($p<.001$) [26•]. Furthermore, the correlation with hypovitaminosis D and DRFs has been found to be independent of BMD [27•].

Seasonal risk factors have also been noted, with disproportionately increased incidence in the winter. In Finland, there was a statistically significant difference between SLFs leading to DRFs in winter (60 %) versus nonwinter (40 %), posited to be the result of an increased fall risk with inclement weather [12•]. Furthermore, a seasonal difference in vitamin D has been demonstrated. One study found that vitamin D levels were significantly lower in patients with DRFs in autumn ($p=.049$) and winter ($p=.001$), with decreased daylight hours as well as less time with skin exposure in the sun [26•]. The change in fall risk and vitamin D absorption in the winter may explain the difference in season-related incidence.

Goals of treatment

The primary goal of treatment is prevention of fracture. While many studies show a correlation of osteoporosis, vitamin D deficiency, and elderly falls with DRFs, there is a paucity of literature regarding preventative treatment of this injury pattern. Maintenance of functional hand and wrist motion is crucial for preservation of independent activities of daily living in the elderly—specifically, in hygiene and feeding. DRFs have also been shown to be a harbinger of hip fractures, which carry significantly higher morbidity as well as mortality risk [28–31]. One study showed that women 60–79 years old who had suffered a fracture of the distal radius had a relative risk of 1.9 (statistically significant with a 95 % CI of 1.3–2.6) of sustaining a hip fracture [30]. Meta-analysis of Colles fracture and the subsequent risk of hip fracture showed a prospective association in both genders, with a significantly stronger association seen in men [31].

Even when the hand is not directly injured, secondary functional deficiencies can occur due to swelling, patient avoidance of hand and finger use, and nerve compression. Edema control measures, such as early postinjury finger and hand mobilization, elevation of the effected extremity, and avoidance of tight casting or prolonged use of a sling, play an important role [11]. Early mobilization of the forearm at the elbow helps prevent elbow stiffness or loss of forearm rotation. In particular, restoration of preinjury (and preimmobilization) supination after immobilization is important for eating and hygiene. Patients often continue to have disability in wrist flexion and extension, as well as superficial deformity; however, this rarely has a significant functional consequence in the elderly [11, 32].

Treatment

The best preventative measure for DRFs and other fragility fractures is osteoporotic management. Current screening guidelines for osteoporosis state that women should receive screening with dual-energy x-ray absorptiometry (DXA) of the hip and lumbar spine at 65 years old. This testing also suggests that for women less than 65 years old with a 10-year fracture, risk is equal to or greater than that of a 65-year-old Caucasian female without additional risk factors. The United States Preventative Services Task Force (USPSTF) does not currently make recommendations regarding screening of men without previous known fractures or secondary causes of osteoporosis or recommendations on the interval for repeat screening intervals, due to a lack of sufficient evidence [33]. Meta-analysis of randomized control trials show statistically insignificant efficacy of treatment with a DXA t -score from –1.0 to –2.5 [34]. However, treatment of patients with a DXA t -score less than –2.5 is indicated with adequate vitamin D and calcium supplementation weight-bearing exercise, as well as pharmacotherapy tailored to the individual patient. Pharmacologic options include bisphosphonates, parathyroid hormone, raloxifene, and estrogen [33].

There is a paucity of literature regarding assessment of vitamin D levels and consequent supplementation in cases of hypovitaminosis D in primary prevention of DRFs. The USPSTF recommends against vitamin D and calcium supplementation in the general population, on the basis of the results of the Women's Health Initiative (WHI) [35, 36•]. The WHI examined 36,282 healthy postmenopausal women from 50 to 79 years old and randomly assigned 400 IU of vitamin D₃ and 1,000 mg of calcium daily versus placebo. The results showed a 1.06 % increase in hip bone density in the treatment arm ($p<.01$) but a nonsignificant reduction in fracture rate. Furthermore, this study found a statistically significant risk of nephrolithiasis with supplementation, with a hazard ratio of 1.17 (95 % CI 1.02–1.34) [34]. While this study showed a nonsignificant reduction in overall fracture rate, there was a

significant reduction in the healthy postmenopausal female subpopulation when they received supplementation [37, 38]. As a result of the current evidence of an association between hypovitaminosis D [25, 26•, 27•] and DRFs, stronger clinical trials evaluating the efficacy of vitamin D assessment and supplementation with either vitamin D alone or vitamin D and calcium are necessary.

Beyond minimizing physiologic risk factors for DRF, an important factor to consider is fall prevention. The most recent literature on fall prevention, the Lifestyle interventions and Independence for Elders Study (LiFE study), suggests functional-based exercise as a focus for the elderly and high-risk fall patients. Self-reported fall incidences per person-year were 1.66, 1.90, and 2.28 in the LiFE therapy, structured exercise, and control groups, respectively; these differences were statistically significant [39•]. While there exist a multitude of specific exercise programs for fall prevention available, concrete data on which specific exercises are superior do not exist. However, these new data suggest that an important factor in improving fall rates is to integrate a strength and balance routine into daily activity, rather than simply having a separate exercise program.

While preventative measures are important to patient care, debate still exists on the acute management of DRFs in the elderly. The treatment paradigm of DRFs for the general population is restoration of anatomy, while the focus in the elderly is restoration of function. Since the use of internal fixation has become widespread, studies suggest that in the general population, better functional outcomes correlate with improved radiographic reduction [40–51]. The elderly population has traditionally been treated with closed reduction and immobilization [52, 53, 54•]. Closed reduction has been shown to fail and result in malunion in over half of cases [54•, 55]. However, a majority of elderly patients have adequate functional outcomes despite imperfect restoration of anatomy [32, 54•, 55–57]. The role of internal fixation in DRFs of the elderly to restore function remains controversial, since there are little data regarding operative indications in the elderly. A retrospective study of 85,924 Medicare patients with a closed DRF explored what factors correlated most strongly with internal fixation. This study found that men were significantly less likely to receive internal fixation than were women (OR- 0.84; 95 % CI 0.80–0.89) and black patients were significantly less likely than were white patients (OR- 0.74; 95 % CI 0.65–0.85) [1, 58•, 59, 60]. Both patient age and the presence of comorbid conditions exhibited a significant negative correlation with the rate of internal fixation. Additionally, there was a great deal of variability in the use of internal fixation based on the treating surgeon. Patients treated by a hand surgeon were significantly more likely to receive internal fixation than were those patients treated by other orthopaedic surgeons. Hand surgeons were more likely to perform internal fixation

over closed treatment, pinning/external fixation, or another treatment with odds ratios of 2.40 (95 % CI 2.21–2.61), 3.22 (95 % CI 2.73–3.80), and 2.49 (95 % CI 2.29–2.70) respectively [58•]. There also exists significant geographic variability in the use of internal fixation among hospital referral regions, ranging from 4.6 % in Paterson, NJ to 42.1 % in Rome, GA. The variability of internal fixation use had a positive correlation with the percent of patients in each referral region who were treated by a hand surgeon, $r=.34$, $p<.0001$ [58•].

In addition to primary prevention and acute management of DRFs, prevention of recurrence or injury with higher morbidity is important. Evaluation of BMD following a DRF—specifically, one resulting from low-energy trauma—is crucial to patient care and is insufficiently provided. Recent evidence suggests that evaluation of osteoporosis and BMD examination should occur in the orthopaedic clinic setting following DRF. Initiation of osteoporosis workup by the orthopedic surgeon results in a statistically significant increase in osteoporosis treatment, as compared with referral to the patient's primary care physician for evaluation [61].

Evaluation for vitamin D deficiency in fragility fractures and geriatric DRFs has slowly become a key component of peri-injury workup. Prospective studies of vitamin D analysis and supplementation following DRF have not been performed, although the association between hypovitaminosis D and DRFs, as well as other fracture patterns, suggests that these studies would be beneficial [25, 26•, 27•]. DRFs have been identified previously as a sentinel event for hip fracture, making hip fracture prevention following DRF an important element of DRF treatment [28–31]. A meta-analysis of the pertinent literature suggests efficacy of vitamin D supplementation in hip fracture prevention [62•]. This study is the most comprehensive and recent study on all of the vitamin D trials on fracture reduction to date. It concludes that high-dose vitamin D supplementation (≥ 800 IU/day) may reduce hip fracture risk in those older than 65 years, independently of age or gender [62•]. Treating DRFs as a sentinel event for hip fracture suggests that it would be reasonable to further explore vitamin D evaluation and supplementation following DRF.

Conclusion

DRFs disproportionately affect women of an advanced age. Those at risk have been shown to have lower BMD, lower vitamin D levels, and an increased risk of fall. The most important treatment modality is prevention of fracture. While standard guidelines for osteoporosis evaluation and treatment have been well studied, the role of vitamin D evaluation and supplementation is promising enough to warrant further randomized study. Furthermore, fall prevention is a promising component of risk reduction in the elderly. We suggest that an exercise program that integrates

strength and balance exercise into daily activities may be superior to independent exercise regimens. Regarding acute DRF management in the elderly, the primary goal is restoration of function. Functional satisfaction in the elderly has been achieved with imperfect anatomic restoration. The ideal method of treatment, internal fixation versus closed management, remains controversial in the elderly. The predominant factors determining use of internal fixation in clinical practice are demographic and geographic, as well as surgical preference. This warrants further study of quantitative surgical indications in DRFs of the elderly.

Following acute management, DRFs can be viewed as a sentinel event for hip fracture. Hip fractures have a higher associated morbidity than do DRFs, and lowering the incidence of this injury pattern following a DRF is important. Recent literature suggests that the burden of assessing BMD following a DRF in the elderly lies with the orthopaedic surgeon, since other means of initial post fracture osteoporosis evaluation have been unreliable. Furthermore, the role of vitamin D evaluation and supplementation merits further review, since the most recent studies suggest that this may reduce the risk of hip fracture. Randomized control trials of appropriate serum vitamin D screening protocols and vitamin D dosing following DRF are necessary to fully determine the role this may play in management. The literature on DRFs in the elderly remains controversial. Patients will benefit from a deeper study of preventative measures, standardized operative indications, and a heightened clinical awareness of the role DRFs may play as a sentinel event for hip fracture.

Disclosure No potential conflicts of interest relevant to this article were reported.

References

Papers of particular interest, published recently, have been highlighted as:

•• Of major importance

1. Chung KC, Spilson SV. The frequency and epidemiology of hand and forearm fractures in the United States. *J Hand Surg Am.* 2001;26:908–15.
2. •• Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. *Hand Clin.* 2012;28(2):113–25. Epub 2012 Apr 14. *This study showed that epidemiological data over the past 40 years have shown an overall increase in prevalence of DRFs, especially in the elderly and pediatric populations.*
3. Melton III L, Amadio P, Crowson C, et al. Long-term trends in the incidence of distal forearm fractures. *Osteoporos Int.* 1998;8:341–8.
4. •• de Putter CE, van Beeck EF, Looman CW, et al. Trends in wrist fractures in children and adolescents, 1997–2009. *J Hand Surg Am.*

- 2011;36:1810–5.e2. *This study showed an increase in the incidence of sports-related DRFs in the pediatric population.*
5. Hagino H, Yamamoto K, Ohshiro H, et al. Changing incidence of hip, distal radius, and proximal humerus fractures in Tottori Prefecture, Japan. *Bone.* 1999;24:265–70.
6. Thompson PW, Taylor J, Dawson A. The annual incidence and seasonal variation of fractures of the distal radius in men and women over 25 years in Dorset, UK. *Injury.* 2004;35:462–6.
7. Brenner H, Arndt V. Epidemiology in aging research. *Exp Gerontol.* 2004;39:679–86.
8. Baron JA, Karagas M, Barrett J, et al. Basic epidemiology of fractures of the upper and lower limb among Americans over 65 years of age. *Epidemiology.* 1996;7:612–8.
9. Schoenborn CA. Health habits of U.S. adults 1985: the “Alameda 7” revisited. *Public Health Rep.* 1985;101:571–80.
10. Rowe JW, Kahn RL. Successful aging. New York: Pantheon Books; 1998.
11. Ring D, Jupiter JB. Treatment of osteoporotic distal radius fractures. *Osteoporos Int.* 2005;16 Suppl 2:S80–4. Epub 2004 Dec 22.
12. •• Flinkkila T, Sirnio K, Hippä M, et al. Epidemiology and seasonal variation of distal radius fractures in Oulu, Finland. *Osteoporos Int.* 2011;22:2307–12. *This study showed that the incidence of DRFs in elderly women in Finland is significantly higher during the winter months. Concurrent weather analysis from the Finnish Meteorological Institute suggests that slipperiness of the pavement could explain the increased winter risk.*
13. Cummings SR, Black DM, Rubin SM. Lifetime risks of hip, Colles’, or vertebral fracture and coronary heart disease among white postmenopausal women. *Arch Intern Med.* 1989;149:2445–8.
14. Singer BR, McLauchlan GJ, Robinson CM, Christie J. Epidemiology of fractures in 15,000 adults: the influence of age and gender. *J Bone Joint Surg.* 1998;80B:243–8.
15. Kanterewicz E, Yanez A, Perez-Pons A, et al. Association between Colles’ fracture and low bone mass: age-based differences in postmenopausal women. *Osteoporos Int.* 2002;13:824–8.
16. Lofman O, Hallberg I, Berglund K, et al. Women with low-energy fracture should be investigated for osteoporosis. *Acta Orthop.* 2007;78:813–21.
17. •• Oyen J, Rohde GE, Hochberg M, et al. Low-energy distal radius fractures in middle-aged and elderly women—seasonal variations, prevalence of osteoporosis, and associates with fractures. *Osteoporos Int.* 2010;21:1247–55. *This study showed that patients who have suffered a DRF who are older than 50 years should be evaluated by bone densitometry because of the increased prevalence of osteoporosis in this population.*
18. •• Oyen J, Brudvik C, Gjesdal CG, et al. Osteoporosis as a risk factor for distal radial fractures: a case-control study. *J Bone Joint Surg Am.* 2011;93:348–56. *This study showed that patients who have suffered a DRF who are older than 50 years should be evaluated by bone densitometry because of the increased prevalence of osteoporosis in this population.*
19. •• Oyen J, Rohde G, Hochberg M, et al. Low bone mineral density is a significant risk factor for low-energy distal radius fractures in middle-aged and elderly men: a case-control study. *BMC Musculoskelet Disord.* 2011;12:67. *This study suggests that since low bone mineral density is a risk factor for low-energy DRF in men older than 50 years, improvement of bone mineral density by both pharmacological and nonpharmacological means may decrease incidence.*
20. •• Melton 3rd LJ, Christen D, Riggs BL, et al. Assessing forearm fracture risk in postmenopausal women. *Osteoporos Int.* 2010;21:1161–9. *This study shows that in postmenopausal women, femoral neck bone mineral densitometry is an adequate test for routine clinical risk assessment of DRF.*
21. Clayton RA, Gaston MS, Ralston SH, et al. Association between decreased bone mineral density and severity of distal radial fractures. *J Bone Joint Surg Am.* 2009;91:613–9.

22. Holick MF. Vitamin D deficiency. *N Engl J Med*. 2007;357:266–81.
23. Bahlous A, Farjallah N, Bouzid K, et al. Hypovitaminosis D in Tunisian osteoporotic postmenopausal women and the relationship with bone fractures. *Tunis Med*. 2009;87:188–90.
24. Bakhtiyarova S, Lesnyak O, Kyznesova N, et al. Vitamin D status among patients with hip fracture and elderly control subjects in Yekaterinburg, Russia. *Osteoporos Int*. 2006;17:441–6.
25. Wright S, Beringer T, Taggart H, Keegan D, Kelly J, Whithead E, et al. A study of male patients with forearm fracture in Northern Ireland. *Clin Rheumatol*. 2007;26:191–5.
26. •• Jang WY, Chung MS, Baek GH, Song CH, Cho HE, Gong HS. Vitamin D levels in post-menopausal Korean women with a distal radius fracture. *Injury*. 2012;43(2):237–41. Epub 2011 Nov 14. *This study shows that postmenopausal women with DRFs had significantly lower vitamin D levels than the control group.*
27. •• Oyen J, Apalset EM, Gjesdal CG, Brudvik C, Lie SA, Hove LM. Vitamin D inadequacy is associated with low-energy distal radius fractures: a case–control study. *Bone*. 2011;48:1140–5. *This study shows an association between vitamin D inadequacy and low-energy DRFs. The differences in vitamin D levels are independent of bone mineral densitometry, body mass index, or smoking history.*
28. Owen RA, Melton 3rd LJ, Ilstrup DM, Johnson KA, Riggs BL. Colles' fracture and subsequent hip fracture risk. *Clin Orthop Relat Res*. 1982;37–43.
29. Mallmin H, Ljunghall S, Persson I, Naessen T, Krusemo UB, Bergstrom R. Fracture of the distal forearm as a forecaster of subsequent hip fracture: a population-based cohort study with 24 years of follow-up. *Calcif Tissue Int*. 1993;52:269–72.
30. Lauritzen JB, Schwarz P, McNair P, Lund B, Transbøl I. Radial and humeral fractures as predictors of subsequent hip, radial or humeral fractures in women, and their seasonal variation. *Osteoporos Int*. 1993;3(3):133–7.
31. Haentjens P, Autier P, Collins J, Velkeniers B, Vanderschueren D, Boonen S. Colles fracture, spine fracture, and subsequent risk of hip fracture in men and women. A meta-analysis. *J Bone Joint Surg Am*. 2003;85-A(10):1936–43.
32. Young BT, Rayan GM. Outcome following nonoperative treatment of displaced distal radius fractures in low-demand patients older than 60 years. *J Hand Surg Am*. 2000;25(1):19–28.
33. U.S. Preventive Services Task Force. Screening for osteoporosis: U.S. preventive services task force recommendation statement. *Ann Intern Med*. 2011;154(5):356–64. Epub 2011 Jan 17.
34. Nelson HD, Haney EM, Dana T, Bougatsos C, Chou R. Screening for osteoporosis: an update for the U.S. Preventive Services Task Force. *Ann Intern Med*. 2010;153(2):99–111.
35. Jackson RD, LaCroix AZ, et al. Calcium plus vitamin D supplementation and the risk of fractures. *N Engl J Med*. 2006;354(7):669–83.
36. •• Kuehn BM. USPSTF: Taking vitamin D and calcium doesn't prevent fractures in older women. *JAMA*. 2012;308(3):225–6. *This study showed no statistically significant decrease in fracture incidence with low-dose vitamin D and calcium supplementation in otherwise healthy women between the ages of 50 and 79 years.*
37. Vieth R, Chan PC, MacFarlane GD. Efficacy and safety of vitamin D3 intake exceeding the lowest observed adverse effect level. *Am J Clin Nutr*. 2001;73:288–94.
38. Aloia JF, Patel M, Dimaano R, et al. Vitamin D intake to attain a desired serum 25-hydroxyvitamin D concentration. *Am J Clin Nutr*. 2008;87:1952–8.
39. •• Clemson L, Fiatarone Singh MA, Bundy A, Cumming RG, Manollaras K, O'Loughlin P, Black D. Integration of balance and strength training into daily life activity to reduce rate of falls in older people (the LiFE study): randomised parallel trial. *BMJ*. 2012;345:e4547. *This study shows that a functional-based exercise program integrated into activities of daily living is more effective at reducing falls in the elderly than are traditional exercise regimens.*
40. Synn AJ, Makhni EC, Makhni MC, Rozental TD, Day CS. Distal radius fractures in older patients: is anatomic reduction necessary? *Clin Orthop Relat Res*. 2009;467(6):1612–20. Epub 2008 Dec 12.
41. Abbaszadegan H, Jonsson U. External fixation or plaster cast for severely displaced Colles' fractures? Prospective 1-year study of 46 patients. *Acta Orthop Scand*. 1990;61:528–30.
42. Fitoussi F, Ip WY, Chow SP. Treatment of displaced intraarticular fractures of the distal end of the radius with plates. *J Bone Joint Surg Am*. 1997;79:1303–12.
43. Howard PW, Stewart HD, Hind RE, Burke FD. External fixation or plaster for severely displaced comminuted Colles' fractures? A prospective study of anatomical and functional results. *J Bone Joint Surg Br*. 1989;71:68–73.
44. Jenkins NH, Jones DG, Mintowt-Czyz WJ. External fixation and recovery of function following fractures of the distal radius in young adults. *Injury*. 1988;19:235–8.
45. Kapoor H, Agarwal A, Dhaon BK. Displaced intra-articular fractures of distal radius: a comparative evaluation of results following closed reduction, external fixation and open reduction with internal fixation. *Injury*. 2000;31:75–9.
46. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am*. 1986;68:647–59.
47. Knox J, Ambrose H, McCallister W, Trumble T. Percutaneous pins versus volar plates for unstable distal radius fractures: a biomechanic study using a cadaver model. *J Hand Surg Am*. 2007;32:813–7.
48. Leung F, Tu YK, Chew WY, Chow SP. Comparison of external and percutaneous pin fixation with plate fixation for intra-articular distal radius fractures. *J Bone Joint Surg Am*. 2008;90:16–22.
49. Merchan EC, Breton AF, Galindo E, Peinado JF, Beltran J. Plaster cast versus Clyburn external fixation for fractures of the distal radius in patients under 45 years of age. *Orthop Rev*. 1992;21:1203–9.
50. Pring DJ, Barber L, Williams DJ. Bipolar fixation of fractures of the distal end of the radius: a comparative study. *Injury*. 1988;19:145–8.
51. Stein H, Volpin G, Horesh Z, Hoerer D. Cast or external fixation for fracture of the distal radius: a prospective study of 126 cases. *Acta Orthop Scand*. 1990;61:453–6.
52. Beharrie AW, Beredjiklian PK, Bozentka DJ. Functional outcomes after open reduction and internal fixation for treatment of displaced distal radius fractures in patients over 60 years of age. *J Orthop Trauma*. 2004;18(10):680–6.
53. Chung KC, Shauver MJ, Birkmeyer JD. Trends in the United States in the treatment of distal radial fractures in the elderly. *J Bone Joint Surg Am*. 2009;91(8):1868–73.
54. •• Diaz-Garcia RJ, Oda T, Shauver MJ, Chung KC. A systematic review of outcomes and complications of treating unstable distal radius fractures in the elderly. *J Hand Surg Am*. 2011;36(5):824–35.e2. *This study shows that in DRF patients older than 60 years, there was no statistically significant difference in functional outcome after treatment with cast immobilization or surgical intervention.*
55. Mackenney PJ, McQueen MM, Elton R. Prediction of instability in distal radial fractures. *J Bone Joint Surg Am*. 2006;88(9):1944–51.
56. Arora R, Gabl M, Gschwentner M, Deml C, Krappinger D, Lutz M. A comparative study of clinical and radiologic outcomes of unstable colles type distal radius fractures in patients older than 70 years: nonoperative treatment versus volar locking plating. *J Orthop Trauma*. 2009;23(4):237–42.
57. Anzarut A, Johnson JA, Rowe BH, Lambert RG, Blitz S, Majumdar SR. Radiologic and patient-reported functional outcomes in an elderly cohort with conservatively treated distal radius fractures. *J Hand Surg Am*. 2004;29(6):1121–7.

58. •• Chung KC, Shauver MJ, Yin H, Kim HM, Baser O, Birkmeyer JD. Variations in the use of internal fixation for distal radial fracture in the United States medicare population. *J Bone Joint Surg Am.* 2011;93(23):2154–62. *This study shows that the use of internal fixation for DRFs differs widely on the basis of geography and patient demographics.*
59. Singer BR, McLauchlan GJ, Robinson CM, Christie J. Epidemiology of fractures in 15,000 adults: the influence of age and gender. *J Bone Joint Surg Br.* 1998;80:243–8.
60. Thomas E, Wilkie R, Peat G, Hill S, Dziedzic K, Croft P. The North Staffordshire Osteoarthritis Project–NorStOP: prospective, 3-year study of the epidemiology and management of clinical osteoarthritis in a general population of older adults. *BMC Musculoskelet Disord.* 2004;5:2.
61. Rozental TD, Makhni EC, Day CS, Bouxsein ML. Improving evaluation and treatment for osteoporosis following distal radial fractures. A prospective randomized intervention. *J Bone Joint Surg Am.* 2008;90(5):953–61.
62. •• Bischoff-Ferrari HA, Willett WC, Orav EJ, Lips P, Meunier PJ, Lyons RA, Flicker L, Wark J, Jackson RD, Cauley JA, Meyer HE, Pfeifer M, Sanders KM, Stähelin HB, Theiler R, Dawson-Hughes B. A pooled analysis of vitamin D dose requirements for fracture prevention. *N Engl J Med.* 2012;367(1):40–9. *This study shows that high-dose vitamin D supplementation (≥ 800 IU daily) was favorable in prevention of hip fracture and any nonvertebral fracture in people who were 65 years or older.*
63. •• Shauver MJ, Clapham PJ, Chung KC. An economic analysis of outcomes and complications of treating distal radius fractures in the elderly. *J Hand Surg Am.* 2011;36(12):1912–8.e1-3. *This study shows that Medicare patients show little economic preference between different treatment modalities for DRFs.*
64. Ray NF, Chan JK, Thamer M, Melton LJ. Medical expenditures for the treatment of osteoporotic fractures in the United States in 1995: report from the National Osteoporosis Foundation. *J Bone Miner Res.* 1997;12:24–35.