

VOLUME

59

2010

Instructional Course Lectures

Mary I. O'Connor, MD
Editor

Kenneth A. Egol, MD
Assistant Editor

AAOS

AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

New Concepts in the Treatment of Distal Radius Fractures

John S. Taras, MD
Amy L. Ladd, MD
David M. Kalainov, MD
David S. Ruch, MD
David C. Ring, MD

Abstract

Fracture of the distal radius is the type of fracture most commonly seen in emergency departments. The understanding of nonsurgical and surgical care of distal radius fractures is evolving with recently developed methods of fixation. It is worthwhile to review some new methods of treatment, the role of bone grafting and synthetic substitutes, the principles of complex fracture management, and the treatment of common complications of distal radius fractures.

Instr Course Lect 2010;59:313-332.

Dr. Taras or an immediate family member is a board member, owner, officer, or committee member of Union Surgical; is a member of a speakers' bureau or has made paid presentations on behalf of Integra Life Sciences; and has received research or institutional support from Axogen. Dr. Ladd or an immediate family member is a board member, owner, officer, or committee member of the American Association for Hand Surgery, the American Society for Surgery of the Hand, the California Orthopaedic Association, the American Board of Orthopaedic Surgery, the American Orthopaedic Association, the Association of Bone and Joint Surgeons, and the Ruth Jackson Orthopaedic Society; has received royalties from the American Society for Surgery of the Hand and Orthohelix; is a member of a speakers' bureau or has made paid presentations on behalf of Medartis; serves as a paid consultant to or is an employee of Acumed; has stock or stock options in Orthovita; and has received nonincome support (such as equipment or services), commercially derived honoraria, or other non-research-related funding (such as paid travel) from the National Institutes of Health (National Institute of Arthritis and Musculoskeletal and Skin Diseases, National Institute of Child Health and Human Development). Dr. Kalainov or an immediate family member is a board member, owner, officer, or committee member of the American Society for Surgery of the Hand and Northwestern Memorial Hospital. Dr. Ruch or an immediate family member serves as a paid consultant to or is an employee of Zimmer and Synthes. Dr. Ring or an immediate family member has received royalties from DePuy and Wright Medical Technology; is a member of a speakers' bureau or has made paid presentations on behalf of Acumed, DePuy, and Synthes; serves as a paid consultant to or is an employee of Acumed and Wright Medical Technology; has received research or institutional support from Acumed, Biomet, Stryker, Tornier, and Joint Active Systems; has stock or stock options in Mimedex and Illuminoss; and has received nonincome support (such as equipment or services), commercially derived honoraria, or other non-research-related funding (such as paid travel) from the Journal of Hand Surgery-American.

Fracture alignment and the age of the patient are the most important factors determining the recovery of function after a distal radius fracture. There is no definitive rule for acceptable fracture alignment, but studies of patients who had a less-than-optimal outcome after healing with malalignment have helped to establish general guidelines. Malalignment and poor outcome are most highly correlated with an intra-articular incongruity exceeding 2 mm.¹⁻⁴ Dorsal angulation of more than 20° is associated with loss of wrist flexion and function.^{1,5,6} Radial shortening of more than 4 mm is associated with loss of forearm rotation, and radial shortening of more than 5 mm is associated with ulnar wrist pain.^{5,7} The relative risk of having a poor outcome was found to be 50% for patients younger than 65 years who had fracture healing with dorsal angulation of more than 10°, radial inclination of less than 15°, or radial shortening of more than 3 mm.⁸ Therefore, reasonable treatment goals for an

Table 1
The Average Range of Motion 12 Months After Surgical Treatment of a Distal Radius Fracture Using Purpose-Designed Threaded Pins

Motion	Measurement
Flexion	54°
Extension	65°
Flexion-extension arc	119° (83% of the contralateral side)
Pronation	83°
Supination	65°
Pronation-supination arc	159° (94% of the contralateral side)

mon complications of external fixation include superficial radial nerve injury and pin tract infection. Stiffness and median nerve dysfunction can result from bridging external fixation because of excessive distraction, although the widespread recognition of this complication has led to greater diligence in avoiding it. The effectiveness of bridging external fixation is somewhat limited by the viscoelastic behavior of ligaments. There is a gradual loss of the initial distraction force applied through stress relaxation, which leads to some loss of initial fracture reduction during the healing phase.^{32,33}

Formal open reduction and internal fixation requires surgical exposure of the fracture components. Plates specifically designed for common distal radius fracture patterns are most useful for fixing a displaced intra-articular fracture,³⁴ although they also are commonly used for unstable extra-articular fractures. Plates can be applied on the volar, dorsal, or radial cortices of the radius to maintain fracture reduction. Some implants incorporate screws that lock into the plate to enhance fracture stability; these designs are particularly useful for fractures with metaphyseal comminution.³⁵ Tendon rupture from chronic irritation over the plate or screws can occur after internal fixation with plates, al-

though this complication is less likely to occur if a newer, low-profile plate design is used.^{29,36} Because of the risk of tendon rupture, care must be taken when applying distal radius plates to ensure that the screws do not penetrate past the far cortex.

Bone Graft Substitutes

An extensive variety of bone graft substitutes is available for use in filling voids and restoring structural integrity during fracture fixation.³⁷⁻³⁹ During the 1980s and 1990s, autogenous bone grafting was developed for use in both external and internal fixation of distal radius fractures, and it now is an important adjunct in the treatment of complex distal radius fractures.⁴⁰⁻⁴² The benefits of autogenous grafting include decreased time required for healing and removal of external fixation, as well as improvements in anatomic and functional outcome. However, autogenous grafting is associated with donor-site morbidity and increased surgical and hospital costs, especially with graft harvesting from the iliac crest⁴³ (Table 2). These disadvantages have influenced both surgeons and entrepreneurs to seek alternatives. Bone graft substitutes have been developed and used throughout the musculoskeletal system, including metaphyseal voids and fractures about the wrist.

Table 2
The Advantages and Disadvantages of Autologous Bone Graft

Advantages
Osteoinductivity and osteoconductivity
Osteogenesis
Cortical and cancellous forms
Structural support
Biocompatibility
Host site incorporation
Remodeling into normal bone
Disadvantages
Limited supply
Variable quality
Difficulty of harvesting
Harvest-related increases in surgical time, hospital stay, and cost
Harvest-related blood loss, postoperative pain, risk of infection, risk of fracture
Potential nidus for infection (avascular bone)

The use of graft substitutes can be considered for a comminuted distal radius fracture with a substantial metaphyseal void. In one respect, choosing a bone graft substitute is no different from choosing an autogenous or allograft bone graft. There is no absolute indication for using graft in the fracture setting, but it may be a useful adjunct.

Recommendations for Fixation of the Wrist Using Bone Graft Substitutes

It is difficult to compare bone graft substitutes of similar composition. These recommendations do not reflect the full range of available substitutes, and they do not constitute an endorsement for using a substitute rather than autogenous or allograft bone. The recommended methods for treating fractures, malunions, and other defects of the distal radius, including the use of bone grafts, are listed in Table 3. These recommendations for the

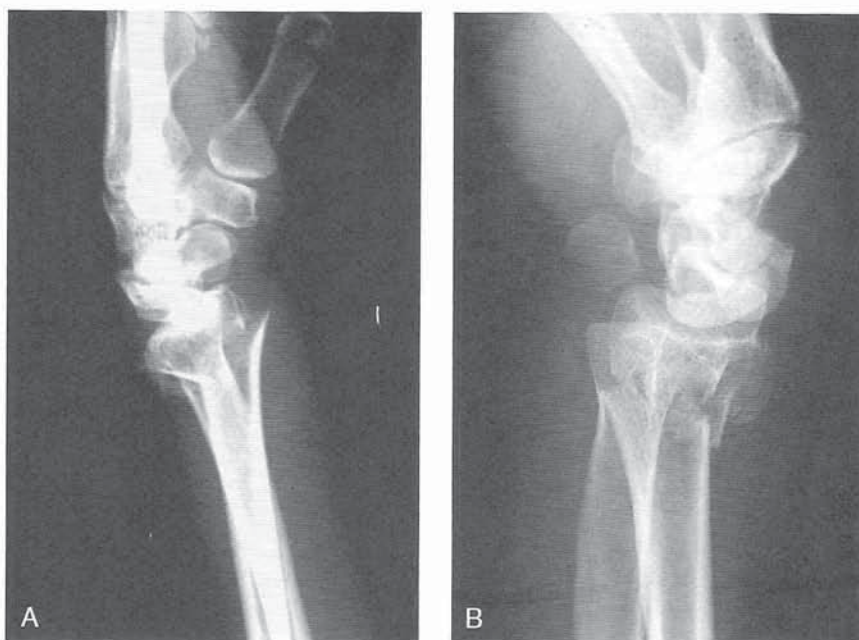


Figure 1 A and B, Lateral radiographs showing two comminuted distal radius fractures susceptible to redisplacement after closed treatment.

active person include a sustained reduction with less than 1 to 2 mm of articular displacement, 10° of dorsal angulation, and 2 to 3 mm of radial shortening.⁹

The optimal evidence-based treatment of distal radius fractures has not yet been clearly defined.¹⁰ A wide array of methods and techniques is available for maintaining fracture alignment, including cast or splint immobilization, percutaneous pinning with casting, bridging or nonbridging external fixation, and internal fixation. The clinician can choose a treatment method based on experience and published research studies.

Pinning Techniques for the Treatment of Extra-articular Distal Radius Fractures

The factors that have been considered in developing procedures to treat extra-articular distal radius fractures include patient age, bone

quality, ability to tolerate the procedure, and fracture type.¹¹ Treatment modalities have progressed from immobilization to percutaneous pinning, pins and plaster, external fixation, and internal fixation. The observed pitfalls of each technique have driven the evolution of treatment modalities. Fractures treated in plaster have a tendency to become redisplaced over time;¹² Mackenney and associates¹³ reported that 60% of initially displaced fractures became redisplaced to a position of malunion when treated in a cast. Lafontaine and associates¹⁴ identified the risk factors for redisplacement after an initial satisfactory reduction of a distal radius fracture as dorsal angulation of more than 20°, comminution, intra-articular involvement, associated fracture of the distal ulna, and patient age older than 60 years; if three or more risk factors were present, the likelihood of fracture collapse was high (Fig-

ure 1). Dias and associates¹⁵ found that osteoporosis is a factor leading to progression of deformity after cast treatment.

The frequent failure of cast immobilization treatment of a displaced distal radius fracture led to attempts at stabilization using hardware fixation. The first widely used method was percutaneous pinning of the reduced fracture, usually with smooth straight wires and occasionally with threaded wires. Most techniques complement the use of pinning with cast immobilization for a period of 4 to 6 weeks. The reported pinning techniques include two pins placed through the radial styloid, two crossed pins, three or four intrafocal pins within the fracture site, transulnar oblique pinning with a threaded wire, a radial styloid pin with a second pin across the distal radioulnar joint, and multiple transulnar to radius pins that included the distal radioulnar joint.¹⁶⁻²⁵

Several studies reported good or excellent results after pinning.^{20,21,25-28} Other studies reported redisplacement rates of 25% to 33% despite pinning and casting.^{16-18,23,24,29} The limitations of standard pinning techniques include a risk of infection if pins are left outside the skin for an extended time, irritation and skin breakdown if a pin cuts beneath the skin, tendon rupture if a pin is in close proximity to extensor tendons, and the necessity of a procedure to remove pins cut beneath the skin.

A purpose-designed threaded pin for distal radius fracture fixation (T-Pin, Union Surgical, Philadelphia, PA) recently has been introduced. This cannulated, threaded pin is designed to hold fracture fragments more securely than the commonly used smooth pins¹¹ (Figure 2). The technique for applying this

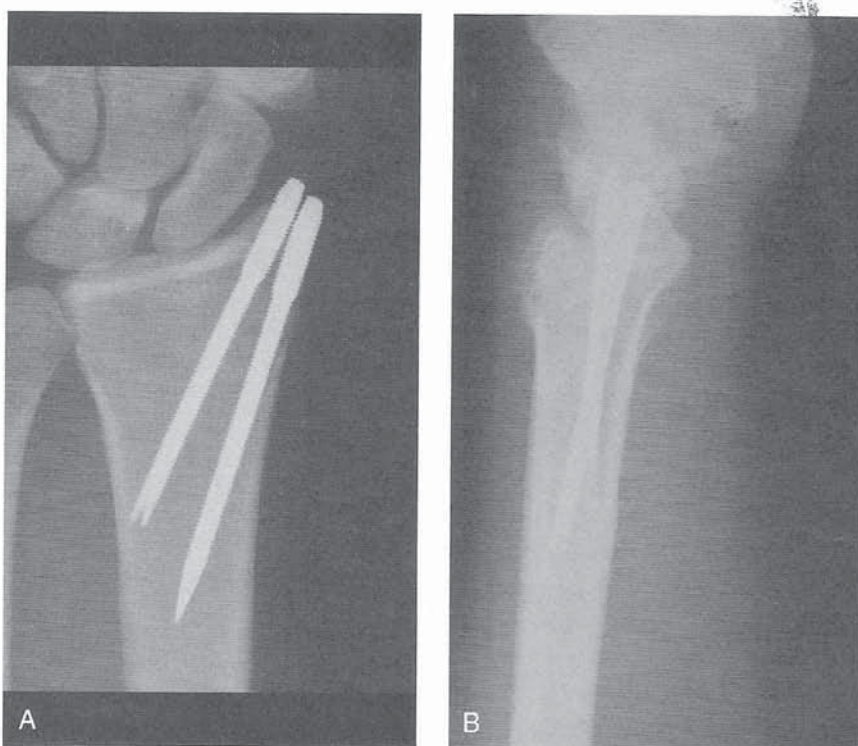


Figure 2 Postfixation PA (A) and lateral (B) radiographs of a distal radius fracture secured with two purpose-designed threaded pins inserted from the radial styloid.

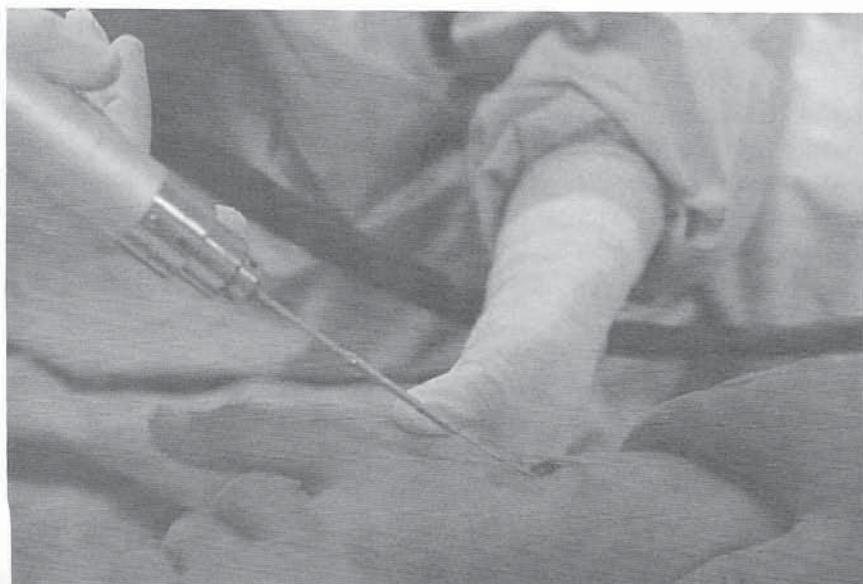


Figure 3 Intraoperative photograph showing the tip of the cannulated purpose-designed pin being placed over guidewire.

fixation device is similar to common pinning techniques. A break-off driver section allows the device to be

placed entirely within the distal radius, thereby eliminating the possibility of tendon or skin irritation.

The primary indication for using the purpose-designed threaded pin is the presence of an unstable, extra-articular, dorsally displaced distal radius fracture.

The purpose-designed threaded pin is placed over a guidewire through a small incision exposing the insertion site (Figure 3). In a typical fixation, two purpose-designed pins are inserted from the radial styloid. Other fixation configurations also can be used. The purpose-designed threaded pin creates a more secure purchase of the fracture fragments than smooth wires and thereby facilitates early wrist range of motion and recovery of function¹¹ (Table 1).

External fixation and internal fixation with plates are widely used alternatives to pinning for an unstable extra-articular distal radius fracture.³⁰ External fixation can bridge the fracture by distal fixation in the metacarpals, thereby indirectly reducing the fracture through ligamentotaxis or by direct distal fixation in the fracture fragment. Bridging external fixation is particularly useful for the initial treatment of an open fracture with soft-tissue loss, as a temporary measure in a patient with polytrauma, and for a distal shear fracture in which the distal fragment cannot be internally fixed. The current trend is to prefer internal fixation over percutaneous and external fixation.³⁰

Nonbridging external fixation has been successfully used for treating unstable extra-articular fractures. At least 1 cm of intact volar cortex is required for pin purchase. In a comparison of bridging and nonbridging external fixation, McQueen³¹ reported that nonbridging fixation led to better radiologic and functional indices during both early and late healing phases. The com-

References

- Forward DP, Davis TR, Sithole JS: Do young patients with malunited fractures of the distal radius inevitably develop symptomatic post-traumatic osteoarthritis? *J Bone Joint Surg Br* 2008;90:629-637.
- Kreder HJ, Hanel DP, Agel J, et al: Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal radius: A randomised, controlled trial. *J Bone Joint Surg Br* 2005;87:829-836.
- Knirk JL, Jupiter JB: Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am* 1986;68:647-659.
- Catalano LW III, Cole RJ, Gelberman RH, Evanoff BA, Gilula LA, Borrelli J Jr: Displaced intra-articular fractures of the distal aspect of the radius: Long-term results in young adults after open reduction and internal fixation. *J Bone Joint Surg Am* 1997;79:1290-1302.
- Altissimi M, Antenucci R, Fiacca C, Mancini GB: Long-term results of conservative treatment of fractures of the distal radius. *Clin Orthop Relat Res* 1986;206:202-210.
- Porter M, Stockley I: Fractures of the distal radius: Intermediate and end results in relation to radiologic parameters. *Clin Orthop Relat Res* 1987;220:241-252.
- Fernandez DL, Geissler WB: Treatment of displaced articular fractures of the radius. *J Hand Surg Am* 1991;16:375-384.
- Grewal R, MacDermid JC: The risk of adverse outcomes in extra-articular distal radius fractures is increased with malalignment in patients of all ages but mitigated in older patients. *J Hand Surg Am* 2007;32:962-970.
- Abramo A, Kopylov P, Tagil M: Evaluation of a treatment protocol in distal radius fractures: A prospective study in 581 patients using DASH as outcome. *Acta Orthop* 2008;79:376-385.
- Handoll HH, Madhok R: Surgical interventions for treating distal radius fractures in adults. *Cochrane Database Syst Rev* 2003;3:CD003209.
- Taras JS, Zambito KL, Abzug JM: T-Pin for distal radius fracture. *Tech Hand Up Extrem Surg* 2006;10:2-7.
- Fernandez DL, Palmer AK: Fractures of the distal radius, in Green D, Hotchkiss R, Pederson W, eds: *Green's Operative Hand Surgery*, ed 4. New York, NY, Churchill Livingstone, 1999, pp 929-985.
- Mackenney PJ, McQueen MM, Elton R: Prediction of instability in distal radial fractures. *J Bone Joint Surg Am* 2006;88:1944-1951.
- Lafontaine MJ, Delince P, Hardy D, Simons M: Instability of fractures of the lower end of the radius: Apropos of a series of 167 cases. *Acta Orthop Belg* 1989;55:203-216.
- Dias JJ, Wray CC, Jones JM: Osteoporosis and Colles' fractures in the elderly. *J Hand Surg Br* 1987;12:57-59.
- Lenoble E, Dumontier C, Goutallier D, et al: Fracture of the distal radius: A prospective comparison between trans-styloid and Kapandji fixations. *J Bone Joint Surg Br* 1995;77:562-567.
- Clancey GJ: Percutaneous Kirschner-wire fixation of Colles fractures: A prospective study of thirty cases. *J Bone Joint Surg Am* 1984;66:1008-1014.
- Stein AH Jr, Katz SF: Stabilization of comminuted fractures of the distal inch of the radius: Percutaneous pinning. *Clin Orthop Relat Res* 1975;108:174-181.
- Kapandji A: Treatment of non-articular distal radius fractures by intrafocal pinning with arum pins, in Saffer P, Cooney WP, eds: *Fractures of the Distal Radius*. Philadelphia, PA, Lippincott Williams & Wilkins, 1995, pp 71-83.
- Kapandji A: Intra-focal pinning of fractures of the distal end of the radius 10 years later. *Ann Chir Main* 1987;6:57-63.
- Kapandji A: L'osteosynthese par double enbrochage intrafocal: Traitement fonctionnel des fractures non-articulaires de l'extrémité inférieure du radius. *Ann Chir* 1976;30:903-908.
- Greatting MD, Bishop AT: Intrafocal (Kapandji) pinning of unstable fractures of the distal radius. *Orthop Clin North Am* 1993;24:301-307.
- DePalma A: Comminuted fractures of the distal end of the radius treated by ulnar pinning. *J Bone Joint Surg Am* 1952;34:651-662.
- Mortier JP, Kuhlmann JN, Richet C, Baux S: Horizontal cubito-radial pinning in fractures of the distal radius including a postero-internal fragment. *Rev Chir Orthop Reparat Appar Mot* 1986;72:567-572.
- Rayhack JM, Langworthy JN, Belsole RJ: Transulnar percutaneous pinning of displaced distal radial fractures: A preliminary report. *J Orthop Trauma* 1989;3:107-114.
- Epinette JA, Lehut JM, Cavenaile M, Bouretz JC, Decoulx J: Pouteau-Colles fracture: Double-closed "basket-like" pinning according to Kapandji. Apropos of a homogeneous series of 70 cases. *Ann Chir Main* 1982;1:71-83.
- Chia B, Catalano LW III, Glickel SZ, Barron OA, Meier K: Percutaneous pinning of distal radius fractures: An anatomic study demonstrating the proximity of K-wires to structures at risk. *J Hand Surg Am* 2009;34:1014-1020.
- Benoist LA, Freeland AE: Buttress pinning in the unstable distal radial fracture: A modification of the Kapandji technique. *J Hand Surg Br* 1995;20:82-96.
- Grewal R, Perey B, Wilmink M, Stothers K: A randomized prospective study on the treatment of intra-articular distal radius fractures: Open reduction and internal fixation with dorsal plating versus mini open reduction, percutaneous fixation, and external fixation. *J Hand Surg Am* 2005;30:764-772.

30. Koval KJ, Harrast JJ, Anglen JO, Weinstein JN: Fractures of the distal part of the radius: The evolution of practice over time. Where's the evidence? *J Bone Joint Surg Am* 2008;90:1855-1861.
31. McQueen MM: Non-spanning external fixation of the distal radius. *Hand Clin* 2005;21:375-380.
32. Winemaker MJ, Chinchalkar S, Richards RS, Johnson JA, Chess DG, King GJ: Load relaxation and forces with activity in Hoffman external fixators: A clinical study in patients with Colles' fractures. *J Hand Surg Am* 1998;23:926-932.
33. Sun JS, Chang CH, Wu CC, Hou SM, Hang YS: Extra-articular deformity in distal radial fractures treated by external fixation. *Can J Surg* 2001;44:289-294.
34. Fernandez DL, Wolfe SW: Distal radius fractures, in Green DP, Hotchkiss RN, Pederson WC, Wolfe SW, eds: *Green's Operative Hand Surgery*, ed 5. New York, NY, Churchill Livingstone, 2005, pp 645-710.
35. Jakob M, Rikli DA, Regazzoni P: Fractures of the distal radius treated by internal fixation and early function: A prospective study of 73 consecutive patients. *J Bone Joint Surg Br* 2000;82:340-344.
36. Ring D, Jupiter JB, Brennwald J, Büchler U, Hastings H II: Prospective multicenter trial of a plate for dorsal fixation of distal radius fractures. *J Hand Surg Am* 1997;22:777-784.
37. Ladd AL, Pliam NB: Use of bone-graft substitutes in distal radius fractures. *J Am Acad Orthop Surg* 1999;7:279-290.
38. Ladd AL, Pliam NB: The role of bone graft and alternatives in unstable distal radius fracture treatment. *Orthop Clin North Am* 2001;32:337-351.
39. Hartigan BJ, Cohen MS: Use of bone graft substitutes and bioactive materials in treatment of distal radius fractures. *Hand Clin* 2005;21:449-454.
40. Seitz WH Jr, Froimson AI, Leb R, Shapiro JD: Augmented external fixation of unstable distal radius fractures. *J Hand Surg Am* 1991;16:1010-1016.
41. Rogachevsky RA, Ouellette EA, Sun S, Applegate B: The use of tricortical cancellous bone graft in severely comminuted intra-articular fractures of the distal radius. *J Hand Surg Am* 2006;31:623-632.
42. Rajan GP, Fornaro J, Trentz O, Zellweger R: Cancellous allograft versus autologous bone grafting for repair of comminuted distal radius fractures: A prospective, randomized trial. *J Trauma* 2006;60:1322-1329.
43. Younger EM, Chapman MW: Morbidity at bone graft donor sites. *J Orthop Trauma* 1989;3:192-195.
44. Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL: Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. *J Bone Joint Surg Am* 1996;78:357-365.
45. Lindau T, Arner M, Hagberg L: Intraarticular lesions in distal fractures of the radius in young adults: A descriptive arthroscopic study in 50 patients. *J Hand Surg Br* 1997;22:638-643.
46. Richards RS, Bennett JD, Roth JH, Milne K Jr: Arthroscopic diagnosis of intra-articular soft tissue injuries associated with distal radial fractures. *J Hand Surg Am* 1997;22:772-776.
47. Forward DP, Lindau TR, Melsom DS: Intercarpal ligament injuries associated with fractures of the distal part of the radius. *J Bone Joint Surg Am* 2007;89:2334-2340.
48. Rosenthal DI, Schwartz M, Phillips WC, Jupiter J: Fracture of the radius with instability of the wrist. *AJR Am J Roentgenol* 1983;141:113-116.
49. Stoffelen D, De Mulder K, Broos P: The clinical importance of carpal instabilities following distal radial fractures. *J Hand Surg Br* 1998;23:512-516.
50. Tang JB: Carpal instability associated with fracture of the distal radius: Incidence, influencing factors and pathomechanics. *Chin Med J (Engl)* 1992;105:758-765.
51. Akahane M, Ono H, Nakamura T, Kawamura K, Takakura Y: Static scapholunate dissociation diagnosed by scapholunate gap view in wrists with or without distal radius fractures. *Hand Surg* 2002;7:191-195.
52. Wright TW, Del Charco M, Wheeler D: Incidence of ligament lesions and associated degenerative changes in the elderly wrist. *J Hand Surg Am* 1994;19:313-318.
53. Short WH, Werner FW, Green JK, Masaoka S: Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate: Part II. *J Hand Surg Am* 2005;30:24-34.
54. Theumann NH, Etehami G, Duvoisin B, et al: Association between extrinsic and intrinsic carpal ligament injuries at MR arthrography and carpal instability at radiography: Initial observations. *Radiology* 2006;238:950-957.
55. Werner FW, Short WH, Green JK, Evans PJ, Walker JA: Severity of scapholunate instability is related to joint anatomy and congruency. *J Hand Surg Am* 2007;32:55-60.
56. Cooney WP III, Dobyns JH, Linscheid RL: Complications of Colles' fractures. *J Bone Joint Surg Am* 1980;62:613-619.
57. Doig SG, Rao SG, Carvell JE: Late carpal instability associated with dorsal distal radial fracture. *Injury* 1991;22:486-488.
58. Dobyns JR, Linscheid RL, Chao EYS, Weber ER, Swanson GE: Traumatic instability of the wrist. *Instr Course Lect* 1975;24:182-199.
59. Brown IW: Volar intercalary carpal instability following a seemingly innocent wrist fracture. *J Hand Surg Br* 1987;12:54-56.
60. Lozano-Calderón SA, Doornberg J, Ring D: Fractures of the dorsal articular margin of the distal part of the radius with dorsal radiocarpal subluxation. *J Bone Joint Surg Am* 2006;88:1486-1493.
61. Taleisnik J, Watson HK: Midcarpal instability caused by malunited frac-