Ulnar Shortening Osteotomy for Distal Radius Malunion

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Abstract

Background Malunion is a common complication of distal radius fractures. Ulnar shortening osteotomy (USO) may be an effective treatment for distal radius malunion when appropriate indications are observed.

Methods The use of USO for treatment of distal radius fracture malunion is described for older patients (typically patients >50 years) with dorsal or volar tilt less than 20 degrees and no carpal malalignment or intercarpal or distal radioulnar joint (DRUJ) arthritis.

Description of Technique Preoperative radiographs are examined to ensure there are no contraindications to ulnar shortening osteotomy. The neutral posteroanterior (PA) radiograph is used to measure ulnar variance and to estimate the amount of ulnar shortening required. An ulnar, mid-sagittal incision is used and the dorsal sensory branch of the ulnar nerve is preserved. An USO-specific plating system with cutting jig is used to create parallel oblique osteotomies to facilitate shortening. Intraoperative fluoroscopy and clinical range of motion are checked to ensure adequate shortening and congruous reduction of the ulnar head within the sigmoid notch.

Results Previous outcomes evaluation of USO has demonstrated improvement in functional activities, including average flexion-extension and pronosupination motions, and patient reported outcomes.

Conclusion The concept and technique of USO are reviewed for the treatment of distal radius malunion when specific indications are observed. Careful attention to detail related to surgical indications and to surgical technique typically will improve range of motion, pain scores, and patient-reported outcomes and will reduce the inherent risks of the procedure, such as ulnar nonunion or the symptoms related to unrecognized joint arthritis.

Level of Evidence: Level IV

Keywords
- distal radius fracture
- malunion
- ulnar shortening osteotomy
- ulnar wrist pain
- ulnar abutment

Ulnar shortening osteotomy (USO) was described first by Milch to treat radial shortening after distal radius fractures.[1] The indications for USO have expanded to include treatment of other etiologies of ulnar-sided wrist pain.[2–5] However, USO continues to be a useful treatment method for distal radius malunion or shortening.[6–10] Although fixation methods for USO have evolved since Milch's original description of osseous wiring,[1] the anatomical and biomechanical principles supporting this method of reconstruction for post-traumatic alterations of distal radius alignment remain largely unchanged. Distal radius fracture displacement and subsequent malunion may cause alterations in the relationships of the distal radius and ulna through the distal radioulnar joint (DRUJ) and may cause secondary effects at the ulnocarpal joint.

Alterations in DRUJ anatomy following injury may involve articular incongruity and/or a displacement of the normal

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surface contact areas of the distal radial sigmoid notch and ulnar head. The DRUJ is a diarthrodial joint; the larger radius of curvature of the concave surface of the sigmoid notch permits the radiocarpal unit to both rotate and translate about the fixed ulna in this inherently unstable joint.[11,12] The morphology of the sigmoid notch includes several different types in the coronal plane, where the articular surface is flat face, ski slope, C shape, or S shape.[13] The influence of these morphological differences on outcomes following injury and on treatment decision-making is not well known; however, increasing awareness of DRUJ mechanics may assist in our understanding of these issues. While the radial head contains the longitudinal axis of rotation for pronosupination at the elbow, the ulnar fovea at the base of the ulnar styloid is the location of the rotational axis at the wrist.[14] Joint stability is imparted by both static and dynamic soft tissue structures. Static stabilizers include the triangular fibrocartilage complex (TFCC) described by Palmer and Werner,[15] composed of the triangular fibrocartilage, meniscus homologue, palmar and dorsal radioulnar ligaments, the extensor carpi ulnaris (ECU) subsheath, and the ulnolunate and lunotriquetral ligaments.[16] The TFCC provides a surface for the ulnar carpus to transmit axial forces, supports the ulnar carpus through ligamentous attachments, and creates a stable attachment for the distal radius to the ulna at the DRUJ. The relative length of the distal ulna to the distal radius, termed ulnar variance, has been described in non-injured wrists in the normal population from –0.13 to –0.29 mm in one study,[17] with the variance shifting by an average of 1.34 mm from full supination to pronation[18,19]

Distal radius malunion is the most common complication of distal radius fractures and can occur in up to 11% of operatively treated fractures and 23% of conservatively managed fractures.[20–23] Normal anatomical parameters have been defined with normal volar tilt of 11 degrees, radial inclination of 22 degrees.[24] Intra-articular malunion of the distal radius may involve articular incongruity at the radiocarpal joint and/or DRUJ, whereas extra-articular fractures may alter surface contact forces and center of rotation for distal radius and ulna mechanics. Complex fractures may involve both intra- and extra-articular malalignment. Atlhough there is no consensus on precise acceptable postinjury radiographic parameters for all patients, there is agreement that volar tilt up to –10 to –15 degrees, radial inclination >15 degrees, radial length between 7 and 15 mm, and ulnar variance <3 mm different from the contralateral side are generally accepted.[24–26]

Regardless of the method for fracture management, relative shortening of the radius leads to an acquired ulnar positive variance that can cause an ulnar impaction syndrome from increased load and shear forces transmitted through the distal ulna.[27] In previous cadaveric studies, increase in ulnar variance by 2.5 mm lead to 42% increase in ulnocarpal loading[27]; as ulnar variance increases, there is an incremental increase in measured force imparted at the ulnocarpal joint.[28] Alterations in the normal relationship of the distal radius and the ulna at the DRUJ can cause increased tensile stress on the TFCC, leading to loss of pronation and supination.[29–33] Likewise, alterations in the normal volar tilt lead to abnormalities in the DRUJ contact and kinematics. Hirahara and colleagues showed the torque required to achieve full DRUJ motion was incrementally increased as the dorsal tilt of the distal radius progressively increased.[34] Nishiwaki and colleagues used a cadaveric distal radius malunion model and revealed that as the distal radius progressively extends, the distal ulna translates distally, ulnarly, and volarly during active supination.[35] Volar translation of the distal ulna was increased after the TFCC was sectioned.[35]

Extra-articular malunions can be classified as involving relative shortening of the radius, a change in the volar tilt or inclination of the distal radius, or both. In radial shortening, the positive ulnar variance may lead to mechanical wear and eventual perforation of the TFCC and impaction of the ulna against the lunate, triquetrum, and lunotriquetral interosseous ligament.[36–38] Some authors suggest that recreating the normal relationship of the length of the distal ulna to the distal radius best restores normal DRUJ kinematics and function.[34,39–43]

Biomechanically, USO decreases the abnormal contact of the ulnar head with the ulnar wrist, resulting in an improved biomechanical relationship of the ulna, radius, and ulnar carpus.[44] When evaluating distal radius malunion with a change in either normal tilt or radial inclination, USO has improved stability of the DRUJ by increasing the tension of the TFCC.[36–38,44–46] This relationship has been shown biomechanically by Nishiwaki and colleagues, where progressive shortening of the ulna led to increased peak contract forces within the DRUJ, thereby increasing the stability of the DRUJ.[44] While most malunions are composed of a combination of deformities in multiple planes, alteration in the normal relationship of the ligamentous structures of the TFCC and the bony articulation of the ulnar head with the sigmoid notch lead to abnormal kinematics.

Patients presenting with malunion of the distal radius can complain of weakness, loss of wrist and forearm motion, decreased grip strength, DRUJ instability, and ulnar-sided wrist pain.[24,26,36,37] On exam, patients may have a prominent distal ulna from volar malunion of the distal radius, or they may have radial deformity of the wrist due to loss of radial inclination. Patients may have pain during supination and pronation of an ulnarly deviated wrist (ulnocarpal stress test).[4] Patients may also have pain during flexion and extension of the ulnarly deviated wrist (TFCC stress test).[4] Radiographically, the deformity of the radius is analyzed in terms of loss of normal inclination, volar tilt, ulnar variance, and compensatory deformities of the proximal and midcarpal rows. A neutral forearm rotation posteroanterior (PA) radiograph is used to determine ulnar variance and compared with the contralateral side if ulnar positive variance is thought to be an etiology of ulnar-sided wrist pain. In the setting of abnormal positive ulnar variance, a >3 mm difference compared with the uninjured side, cystic changes in the ulnar head, ulnar aspect of the lunate, or radial aspect of the triquetrum can be visualized.[4] The DRUJ, radiocarpal, and midcarpal joints are analyzed to evaluate for advanced signs

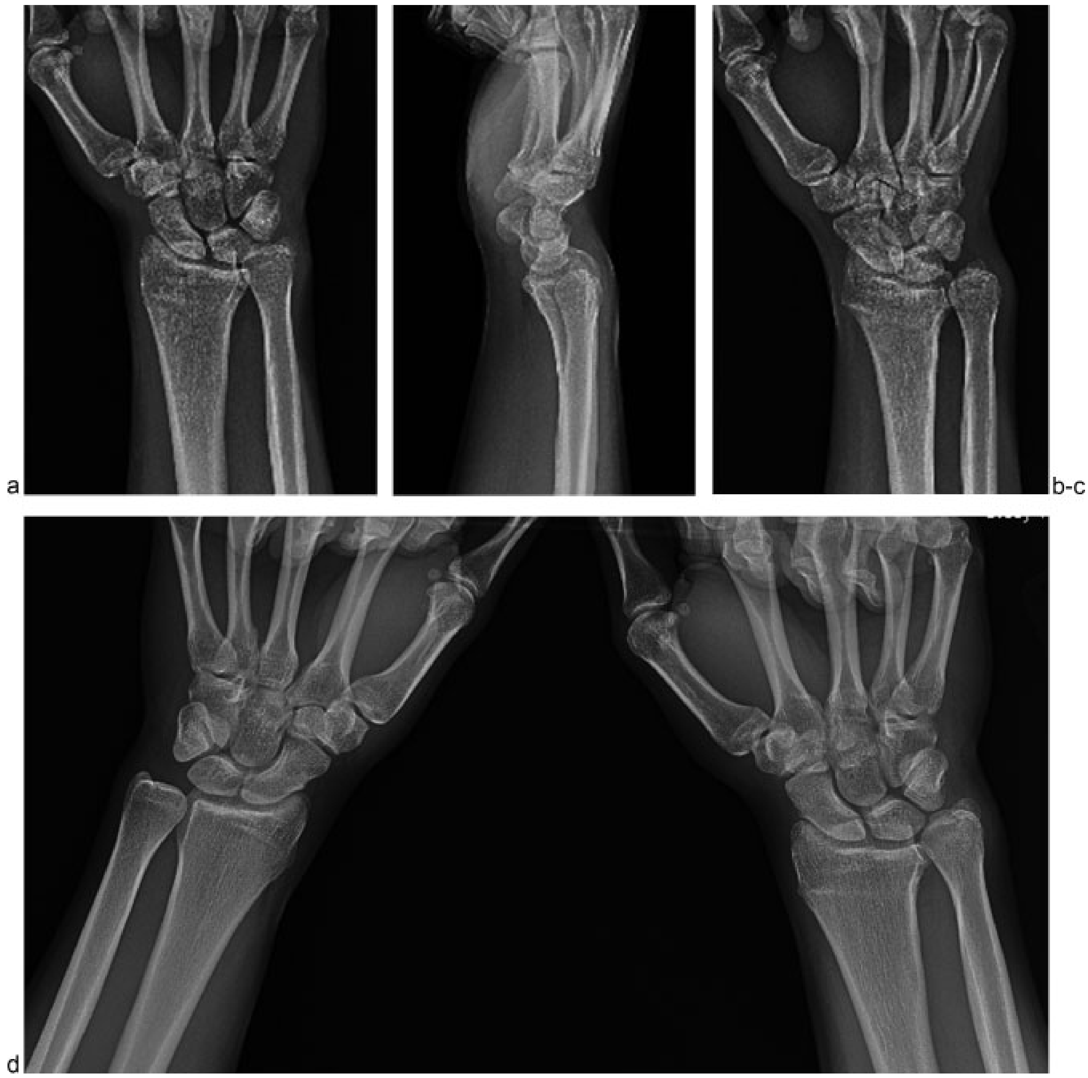

Fig. 1a–d Neutral forearm rotation PA (**a**) latera,l (**b**) and oblique, (**c**) views are obtained to evaluate radiographic outcomes following a distal radius fracture. Comparison views with the contralateral wrist (**d**) may assist in assessment of ulnar variance.

of arthritis, as its presence may influence reconstructive options. (►**Figs. 1a–d**)

Methods

Uso for distal radius malunion is indicated for patients who have failed conservative management and are not candidates for corrective osteotomy of the distal radius malunion. Because of the risk of associated development of radiocarpal arthrosis, Srinivasan et al have recommended that patients be older than 50 with dorsal or volar tilt less than 20 degrees.[7] Because USO corrects only the relationship of the distal ulna to the carpus and sigmoid notch, any preoperative carpal malalignment or radiocarpal/midcarpal arthritis are relative contraindications to surgery. Distal radius dorsal tilt greater than 20 degrees may be considered as relative contraindications due to the limitations posed by the radial malunion, uncorrectable by USO. Pre-existing DRUJ arthritis can be exacerbated by USO and should be considered as a contraindication.

Multiple surgical techniques and osteotomy positions on the ulna have been described for USO.[19] USO through the ulnar diaphysis has been described using parallel oblique[47] or transverse[46] cuts, as well as complementary step cuts.[47] All techniques require that attention be paid to rotation of the ulna, and must provide for adequate bone contact to minimize the risk of nonunion or malunion. To facilitate control of rotation, various cutting jigs have been described that use parallel cuts, to control the amount of ulnar shortening.[48] Recently, Greenberg and colleagues described USO using an extra-articular distal metaphyseal osteotomy.[49] Preoperative, neutral, posteroanterior radiographs should be evaluated to estimate the amount of ulnar shortening needed to recreate the normal proximal-distal relationship of the ulna with the sigmoid notch, ensuring it to be ulnar negative.

Surgical Technique

We prefer an USO-specific cutting jig system that creates parallel oblique cuts in the ulnar diaphysis. The patient is placed supine on the operating table and a well-padded

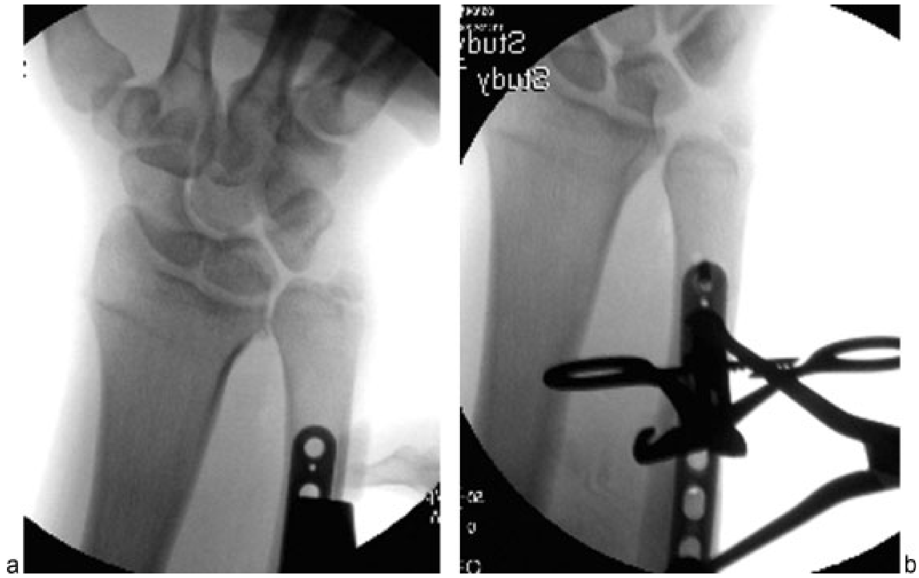

Fig. 2 (a) Intraoperative radiographs are obtained to evaluate plate placement prior to osteotomy. **(b)** Successful shortening is aided by a standardized cutting jig and reduction clamps.

tourniquet is used on the upper arm. The procedure is completed on a hand table either with an assistant holding the elbow flexed or by extending the arm and placing bumps underneath the elbow with the forearm supinated. A traction tower using finger traps may also be used without traction applied to facilitate forearm positioning. The ulna is exposed using the interval between the flexor carpi ulnaris (FCU) and ECU muscles. Care is taken to protect the dorsal sensory branch of the ulnar nerve. Retractors are placed volarly and dorsally to protect the soft tissues and the jig is applied to the ulna, allowing for parallel osteotomies. Preoperative imaging is reviewed to measure the amount of ulna that must be excised to recreate normal ulnar length with the sigmoid notch. A standard 3.5 mm six- or seven-hole compression plate that allows lag screw fixation and compression is used as part of the jig for fixation of the osteotomy (►**Figs. 2a,b**). Recently, a study by Martin and colleagues presented at the 2014 Annual Meeting of the American Academy of Orthopaedic Surgeons determined that a perpendicular clamp compression method provided improved osteotomy site compression compared with traditional compression screw technique and that the addition of a lag screw increased compression also[50] (personal communication, Dan A. Zlotolow, M.D., March 2014) Prior to fixation of the osteotomy, fluoroscopy is used to confirm appropriate shortening and alignment of the ulna, relative to the radius and sigmoid notch (►**Figs. 3a,b**). Wrist and forearm range of motion is evaluated for joint congruity. Following osteotomy stabilization and wound closure, the patient is placed into a padded plaster or fiberglass splint that is converted to a short arm orthoplast

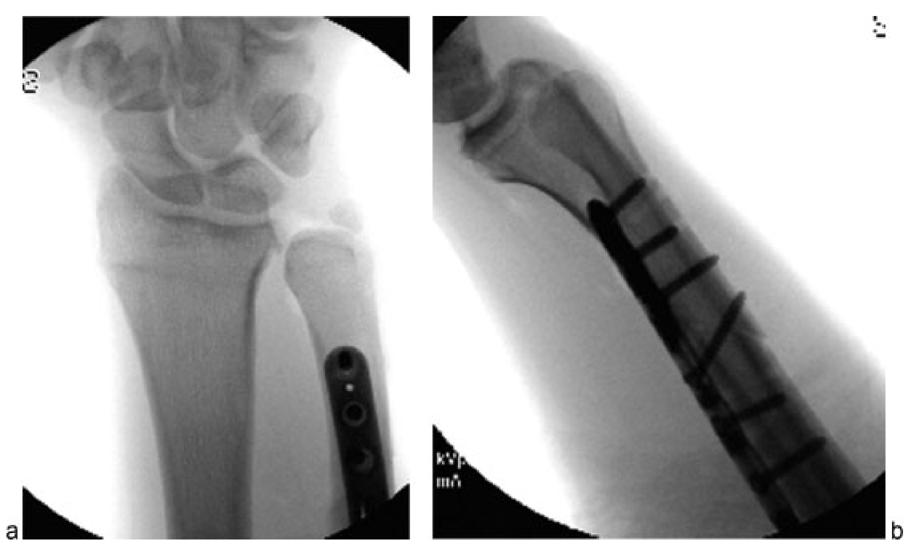

Fig. 3 Neutral forearm rotation PA (**a**) and lateral (**b**) radiographs demonstrate distal radioulnar alignment following osteotomy.

splint at 2 weeks. A home-based therapy regimen of wrist and finger range of motion is initiated, and patients are restricted to lifting, pulling, and torsional activity against resistance of no more than 1 lb. Serial radiographs are obtained, commensurate with osseous healing. Weight bearing is not advanced until signs of osseous healing are observed radiographically, typically at 10–12 weeks postoperatively.

Results

Outcomes of USO for the treatment of distal radius malunion have been described, although reports have been limited to small case series. Srinivasan et al described USO for distal radius malunion in 18 patients with an average of 5.6 mm of shortening of the ulna. They showed statistically significant improvement in objective range of motion; average flexion-extension arc improved from 79 to 105 degrees and pronosupination arc increased from 121 to 162 degrees. Patient-reported outcomes improved significantly with average visual analog scale (VAS) pain score decreasing from 4.1 to 1.9, and Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score decreasing from 43 to 11.[7] Fricker and colleagues described USO for distal radius malunion in 20 patients as part of a larger cohort and described high satisfaction unless there was preoperative DRUJ arthritis.[6] Oskam et al also published a series of 10 patients treated with USO. They had a relatively high complication rate with four nonunions and two poor functional outcomes. The authors attributed these poor results to patients with a volar radiocarpal angle greater than 20 degrees.[10] Tatebe et al completed USO on 16 patients for distal radius malunion and showed improved flexion-extension (81 to 103 degrees), pronsupination arc (120 to 142 degrees), and grip strength (49 to 69%).[8]

Discussion

USO has been shown to be an affective treatment option for distal radius malunion for specific indications. Biomechanically, USO prevents pathologic articular contact of the ulnar head with the ulnar carpus, while improving the normal relationship and soft tissue constraints between the distal ulna and sigmoid notch of the radius. The appropriate patient, with age-appropriate functional requirements, no pre-existing DRUJ arthritis, and malunion $<$20 degrees, can be successfully treated with USO with predictable functional improvement. Complications from USO, although uncommon, include nonunion or malunion of the osteotomy and hardware irritation necessitating removal. Although multiple surgical techniques for USO have been described, correcting the proximal-distal relationship of the ulna to the malunited radius and to the carpus may provide reasonable outcomes for the challenging condition of distal radius malunion.

Conflict of Interest
None

References

1 Milch H. So-called dislocation of the lower end of the ulna. Ann Surg 1942;116(2):282–292
2 Yin HW, Qiu YQ, Shen YD, Xu JG, Gu YD, Xu WD. Arthroscopic distal metaphyseal ulnar shortening osteotomy for ulnar impaction syndrome: a different technique. J Hand Surg Am 2013;38(11): 2257–2262
3 Cha SM, Shin HD, Kim KC, Park E. Ulnar shortening for adolescent ulnar impaction syndrome: radiological and clinical outcomes. J Hand Surg Am 2012;37(12):2462–2467
4 McBeath R, Katolik LI, Shin EK. Ulnar shortening osteotomy for ulnar impaction syndrome. J Hand Surg Am 2013;38(2): 379–381
5 Lee JI, Suh DH, Byun JS, et al. Radiographic appearance and patient outcome after ulnar shortening osteotomy for idiopathic ulnar impaction syndrome. J Hand Surg Am 2012;37(5):975–981
6 Fricker R, Pfeiffer KM, Troeger H. Ulnar shortening osteotomy in posttraumatic ulnar impaction syndrome. Arch Orthop Trauma Surg 1996;115(3-4):158–161
7 Srinivasan RC, Jain D, Richard MJ, Leversedge FJ, Mithani SK, Ruch DS. Isolated ulnar shortening osteotomy for the treatment of extra-articular distal radius malunion. J Hand Surg Am 2013; 38(6):1106–1110
8 Tatebe M, Shinohara T, Okui N, Yamamoto M, Imaeda T, Hirata H. Results of ulnar shortening osteotomy for ulnocarpal abutment after malunited distal radius fracture. Acta Orthop Belg 2012; 78(6):714–718
9 Oskam J, Bongers KM, Karthaus AJ, Frima AJ, Klasen HJ. Corrective osteotomy for malunion of the distal radius: the effect of concomitant ulnar shortening osteotomy. Arch Orthop Trauma Surg 1996; 115(3-4):219–222
10 Oskam J, Kingma J, Klasen HJ. Ulnar-shortening osteotomy after fracture of the distal radius. Arch Orthop Trauma Surg 1993; 112(4):198–200
11 af Ekenstam F, Hagert CG. Anatomical studies on the geometry and stability of the distal radio ulnar joint. Scand J Plast Reconstr Surg 1985;19(1):17–25
12 af Ekenstam FW, Palmer AK, Glisson RR. The load on the radius and ulna in different positions of the wrist and forearm. A cadaver study. Acta Orthop Scand 1984;55(3):363–365
13 Tolat AR, Stanley JK, Trail IA. A cadaveric study of the anatomy and stability of the distal radioulnar joint in the coronal and transverse planes. J Hand Surg [Br] 1996;21(5):587–594
14 Kleinman WB. Stability of the distal radioulna joint: biomechanics, pathophysiology, physical diagnosis, and restoration of function: what we have learned in 25 years. J Hand Surg Am 2007;32(7): 1086–1106
15 Palmer AK, Werner FW. The triangular fibrocartilage complex of the wrist—anatomy and function. J Hand Surg Am 1981;6(2): 153–162
16 Nakamura T, Yabe Y, Horiuchi Y. Functional anatomy of the triangular fibrocartilage complex. J Hand Surg [Br] 1996;21(5): 581–586
17 Freedman DM, Edwards GS Jr, Willems MJ, Meals RA. Right versus left symmetry of ulnar variance. A radiographic assessment. Clin Orthop Relat Res 1998;(354):153–158
18 Jung JM, Baek GH, Kim JH, Lee YH, Chung MS. Changes in ulnar variance in relation to forearm rotation and grip. J Bone Joint Surg Br 2001;83(7):1029–1033
19 Constantine KJ, Tomaino MM, Herndon JH, Sotereanos DG. Comparison of ulnar shortening osteotomy and the wafer resection procedure as treatment for ulnar impaction syndrome. J Hand Surg Am 2000;25(1):55–60
20 Pogue DJ, Viegas SF, Patterson RM, et al. Effects of distal radius fracture malunion on wrist joint mechanics. J Hand Surg Am 1990; 15(5):721–727

21 Slagel BE, Luenam S, Pichora DR. Management of post-traumatic malunion of fractures of the distal radius. Hand Clin 2010;26(1):71–84

22 Slagel BE, Luenam S, Pichora DR. Management of post-traumatic malunion of fractures of the distal radius. Orthop Clin North Am 2007;38(2):203–216, vi vi.

23 Prommersberger KJ, Froehner SC, Schmitt RR, Lanz UB. Rotational deformity in malunited fractures of the distal radius. J Hand Surg Am 2004;29(1):110–115

24 Bushnell BD, Bynum DK. Malunion of the distal radius. J Am Acad Orthop Surg 2007;15(1):27–40

25 Nana AD, Joshi A, Lichtman DM. Plating of the distal radius. J Am Acad Orthop Surg 2005;13(3):159–171

26 Graham TJ. Surgical correction of malunited fractures of the distal radius. J Am Acad Orthop Surg 1997;5(5):270–281

27 Palmer AK, Werner FW. Biomechanics of the distal radioulnar joint. Clin Orthop Relat Res 1984;(187):26–35

28 Markolf KL, Tejwani SG, Benhaim P. Effects of wafer resection and hemiresection from the distal ulna on load-sharing at the wrist: a cadaveric study. J Hand Surg Am 2005;30(2):351–358

29 Adams BD. Effects of radial deformity on distal radioulnar joint mechanics. J Hand Surg Am 1993;18(3):492–498

30 Bell MJ, Hill RJ, McMurtry RY. Ulnar impingement syndrome. J Bone Joint Surg Br 1985;67(1):126–129

31 Bronstein AJ, Trumble TE, Tencer AF. The effects of distal radius fracture malalignment on forearm rotation: a cadaveric study. J Hand Surg Am 1997;22(2):258–262

32 Hollingsworth R, Morris J. The importance of the ulnar side of the wrist in fractures of the distal end of the radius. Injury 1976;7(4):263–266

33 Werner FW, Palmer AK, Fortino MD, Short WH. Force transmission through the distal ulna: effect of ulnar variance, lunate fossa angulation, and radial and palmar tilt of the distal radius. J Hand Surg Am 1992;17(3):423–428

34 Hirahara H, Neale PG, Lin YT, Cooney WP, An KN. Kinematic and torque-related effects of dorsally angulated distal radius fractures and the distal radial ulnar joint. J Hand Surg Am 2003;28(4):614–621

35 Nishiwaki M, Nakamura T, Nagura T, Toyama Y, Ikegami H. Ulnar-shortening effect on distal radioulnar joint pressure: a biomechanical study. J Hand Surg Am 2008;33(2):198–205

36 Friedman SL, Palmer AK. The ulnar impaction syndrome. Hand Clin 1991;7(2):295–310

37 Chun S, Palmer AK. The ulnar impaction syndrome: follow-up of ulnar shortening osteotomy. J Hand Surg Am 1993;18(1):46–53

38 Loh YC, Van Den Abbeele K, Stanley JK, Trail IA. The results of ulnar shortening for ulnar impaction syndrome. J Hand Surg [Br] 1999;24(3):316–320

39 Hollevoet N, Verdonk R. The functional importance of malunion in distal radius fractures. Acta Orthop Belg 2003;69(3):239–245

40 Batra S, Gupta A. The effect of fracture-related factors on the functional outcome at 1. year in distal radius fractures. Injury 2002;33(6):499–502

41 Bickerstaff DR, Bell MJ. Carpal malalignment in Colles' fractures. J Hand Surg [Br] 1989;14(2):155–160

42 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

43 Solgaard S. Function after distal radius fracture. Acta Orthop Scand 1988;59(1):39–42

44 Nishiwaki M, Nakamura T, Nakao Y, Nagura T, Toyama Y. Ulnar shortening effect on distal radioulnar joint stability: a biomechanical study. J Hand Surg Am 2005;30(4):719–726

45 Darrow JC Jr, Linscheid RL, Dobyns JH, Mann JM III, Wood MB, Beckenbaugh RD. Distal ulnar recession for disorders of the distal radioulnar joint. J Hand Surg Am 1985;10(4):482–491

46 Minami A, Kato H. Ulnar shortening for triangular fibrocartilage complex tears associated with ulnar positive variance. J Hand Surg Am 1998;23(5):904–908

47 Darlis NA, Ferraz IC, Kaufmann RW, Sotereanos DG. Step-cut distal ulnar-shortening osteotomy. J Hand Surg Am 2005;30(5):943–948

48 Rayhack JM, Gasser SI, Latta LL, Ouellette EA, Milne EL. Precision oblique osteotomy for shortening of the ulna. J Hand Surg Am 1993;18(5):908–918

49 Greenberg JA, Werner FW, Smith JM. Biomechanical analysis of the distal metaphyseal ulnar shortening osteotomy. J Hand Surg Am 2013;38(10):1919–1924

50 Martin DEZD, Russo SA, Kozin SH. Comparison of compression screw and perpendicular clamp in ulnar shortening osteotomy. *American Academy of Orthopaedic Surgeons Annual Meeting.* 2014