Sustentaculum Lunatum: Appreciation of the Palmar Lunate Facet in Management of Complex Intra-Articular Fractures of the Distal Radius

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Abstract

Fracture of the distal radius is the most common wrist injury. Treatment of complex intra-articular fractures of the distal radius requires an accurate diagnosis of the fracture pattern and a thoughtful approach to fixation. We propose a new term, *sustentaculum lunatum*, for the palmar lunate facet. The sustentaculum lunatum deserves specific attention because of its importance in load transmission across the radiocarpal joint. It is also key to restoring the anatomy of the palmar distal radial metaphysis during internal fixation. We provide a review of the structure and function of the sustentaculum lunatum and describe fixation techniques. This article is intended to promote awareness of this fragment in the treatment of fractures of the distal radius.

Fracture of the distal radius is the wrist injury most often encountered by orthopedic and hand surgeons.[1] The number of fractures of the distal radius in the United States was estimated to be 640,000 in 2001, and the incidence is increasing.[2,3] Recent evidence has shown a substantial increase in treating these fractures with internal rather than closed fixation, even in the elderly.[4]

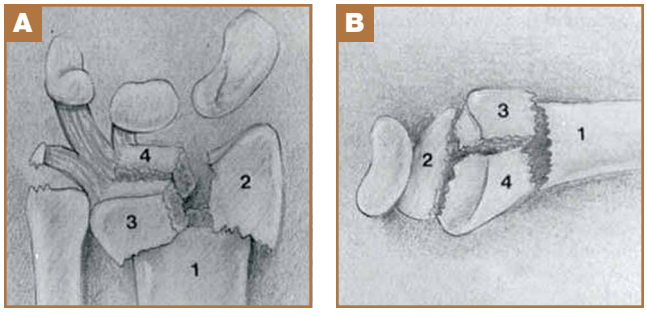
Treatment of complex intra-articular fractures of the distal radius requires an accurate diagnosis of the fracture pattern and a thoughtful approach to fixation. Although a majority of the fractures that meet the operative criteria are now treated with various anterior locked-plating techniques with good results, a subset requires more technically demanding fixation approaches, including fragment-specific approaches, dorsal and palmar plating, and combined internal and external fixation.

The *sustentaculum lunatum*, as we have named the palmar lunate facet, deserves specific attention because of its importance in load transmission across the radiocarpal joint and its key role in restoring the anatomy of the palmar distal radial metaphysis during internal fixation. This fragment in comminuted fractures was first ascribed special importance by Melone[5] in his description of common fracture patterns. In the present article, we describe the anatomical characteristics of the sustentaculum lunatum and the clinical relevance of this fragment to management of fractures of the distal radius.

Classification

A variety of classification systems have been proposed to characterize and guide treatment of fractures of the distal radius. The earliest descriptions of fracture patterns were presented by Castaing[6] and Frykman[7] in the 1960s. The Frykman classification historically has been popular but is limited in accuracy in its characterization of fragments and their displacement and is limited in its ability to guide treatment. The classification system proposed by Melone and colleagues[5,8-10] was the first to truly describe fracture of the distal radius fragments in a relevant manner, including their characteristic "4 parts" (**Figure 1**). The

Figure 1. (A) Anteroposterior and (B) lateral views of articular fractures show 4 basic components: metaphyseal or shaft fragments, radial styloid fragments, dorsal medial fragments, and palmar medial fragments. This figure was published in *Orthopaedic Clinics of North America*, vol. 24, CP Melone Jr, Distal Radius Fractures: Patterns of Articular Fragmentation, pages 239-253, Copyright Elsevier 1993.



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authors emphasized the importance of the "medial complex" as the cornerstone of the radiocarpal and radioulnar joints.

The classification system developed by Müller and colleagues,[11] which was adopted by the AO (Arbeitsgemeinschaft für Osteosynthesefragen), might be the most descriptive and informative system, and it is widely used to conduct research and direct treatment. This system classifies fractures into A (extra-articular), B (partial articular), and C (complete articular) types and subclassifies them according to fracture location and comminution. These classifications, along with a conceptualization of the distal forearm as a 3-column structure involving the radial, ulnar, and intermediate columns (including the lunate facet), as proposed by Peine and colleagues,[12] gave us a framework for approaching fixation of fractures of the distal radius.

Etymology and Definition

Sustentaculum, from the Latin *sustinere*, "to support, check, or put off," and *taculum*, "receptacle or holding space," is a fitting description of the most distal portion of the palmar lunate facet, as it supports and holds the carpus, and specifically the lunate, on the radial articular surface. This portion is analogous to the sustentaculum tali, the named portion of the calcaneus that supports and articulates with the middle calcaneal articular surface of the talus[13] and provides a reliable fragment for internal fixation of the calcaneus.

Anatomical and Biomechanical Considerations

The distal radial articular surface is composed of distinct scaphoid and lunate facets that articulate with their respective carpal bones. Several studies have characterized the anatomy of the distal radius.[14-17] Linscheid[14] found that the lunate and scaphoid facets account for 46% and 43% of the contact area across the radiocarpal joint, respectively; this has been corroborated by others.[15] A biomechanical study by Genda and Horii[18] showed that the majority of stress across the wrist joint was concentrated at the palmar side of the distal radius in the neutral position. Although it is recognized that the scaphoid facet bears most of the load across the wrist in the neutral wrist position, most activities of daily living place the wrist in a slightly extended and ulnarly deviated position. This position results in a shift of the majority of load to the radiolunar articulation, constituting 53% of total force transmission.[18] Subchondral bone density analyses have supported this lunate-predominant loading pattern across the radiocarpal articulation in most people.[19] This loading pattern is also supported by the observation that failure of fixation and carpal subluxation generally occurs at the radiolunate articulation.

The palmar lip of the distal radius traditionally has been depicted and conceptualized as a flat extension of the metaphysis, leading to the development of implants that are not ideally designed for capturing this area in the fracture setting. A 3-dimensional (3-D) computed tomography (CT) study of the distal radii of healthy volunteers, conducted by Andermahr and colleagues,[20] showed that the contour of the palmar lunate facet projects from the palmar cortex of the radius by 3 mm on average and is about 19 mm in width (radial to ulnar dimension) (**Figures 2A–2C**). In the axial plane, the anterior cortex of the distal radius slopes in a palmar direction, from radial to ulnar. This presents a challenge in attempts to support the entire surface (scaphoid and lunate facets) with a single palmar implant.[20-25]

A study conducted by Harness and colleagues[24] showed that the majority of palmar shear fractures are composed of multiple fragments of the lunar articular facet. Anatomical studies of the distal radiocarpal articulation have also described the ligamentous attachments to the sustentaculum lunatum.[26] The short radiolunate ligament, which originates from this fragment and inserts onto the lunate, provides stability to the carpus and, if not adequately fixed, leads to an incompetent restraint to palmar carpal translation. Isolated injuries of the short radiolunate ligament or fractures of the palmar lunate facet have been shown to result in palmar carpal translation.[27,28] In addition, attachments of the palmar radioulnar ligament and other more ulnar radiocarpal ligaments act as deforming forces on the palmar lunate facet.[24,26]

Fracture Pattern Recognition

Although the AO type B palmar shear fracture pattern, also known as the Barton fracture, has classically been recognized as the fracture involving the palmar lunate facet and requiring special attention, many complete articular fractures feature involvement and fragmentation of this portion of the distal radius (**Figures 3A–3F**).[29] In highly comminuted complete articular and palmar shear fracture patterns, the morphology of the sustentaculum

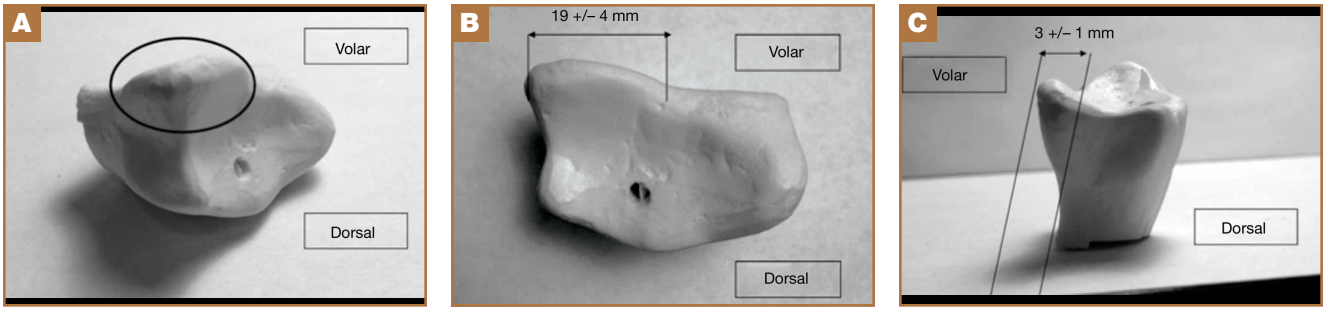

Figure 2. (A) Oblique view of distal radius shows volar extension of lunate articular surface. (B) Axial view shows plane defined as width of volar extension of lunate facet. (C) Lateral view from ulnar side shows plane defined by volar surface of distal radius and extent of lunate facet anterior to plane.

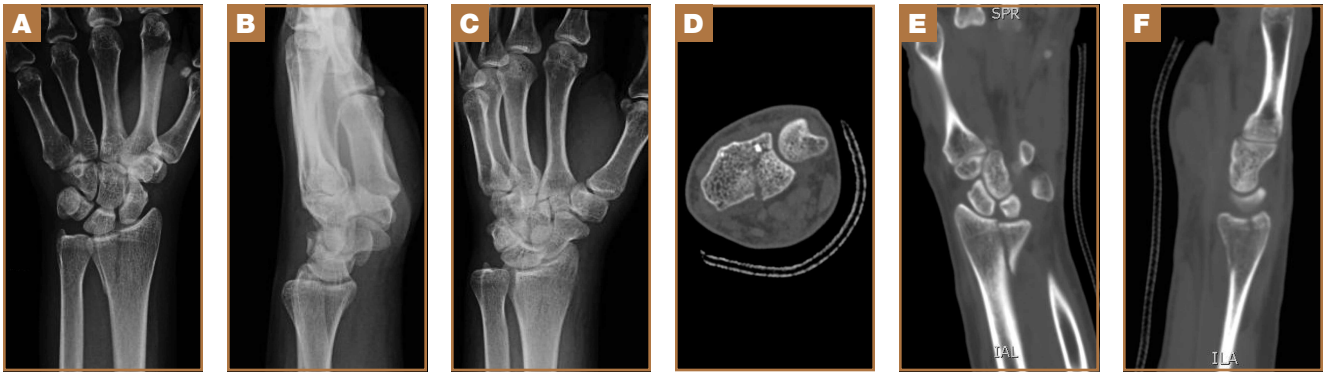

Figure 3. Isolated fracture of lunate facet demonstrates anterior translation and step-off, as seen on (A) anteroposterior, (B) lateral, and (C) oblique radiographs and on (D) axial, (E) coronal, and (F) sagittal computed tomography.

lunatum should be appreciated, and its adequate fixation to the radial metaphysis ensured, to prevent loss of reduction.

Visualization of the palmar lunate facet as a distinct fragment might be difficult in cases of highly comminuted fracture patterns. Standard CT or more recently described 3-D CT techniques with subtraction of the carpus might facilitate appreciation of this fragment for preoperative planning of approach and fixation.[29,30] Our institutional protocol involves obtaining preoperative traction radiographs of every fracture of the distal radius. These radiographs have reduced the need for CT in understanding the fracture pattern and aid in decision making.[31]

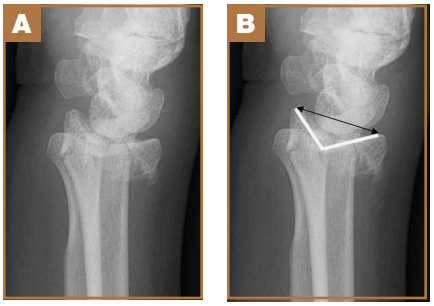

Figure 4. (A) Lateral view traction radiograph. (B) V sign (white lines) and increased anteroposterior dimension (black arrow) represent lunate facet split into unstable dorsal and palmar fragments.

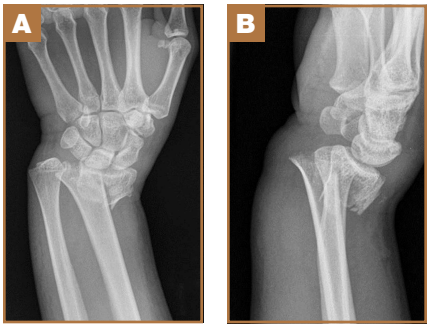

Figure 5. (A) Anteroposterior and (B) lateral radiographs of open fracture of distal radius show relatively noncomminuted palmar radial metaphyseal spike.

Besides appreciating the existence of the sustentaculum lunatum fragment, we should recognize that some injury patterns that split the lunate facet into unstable dorsal and palmar fragments might necessitate a separate dorsal approach to reduce and fix the dorsal lunate fragment. Traction radiographs can be especially useful in recognizing these patterns (a V sign is present) (**Figures 4A, 4B**).

Open Fractures

Highly comminuted fractures of the distal radius presenting with displaced lunate facet fragments can have high-energy mechanisms of injury. Although open fractures of the distal radius are associated with lower risk for infection (compared with open fractures of other long bones), they deserve special attention because of associated tendon and neurovascular injuries. Few studies have specifically assessed open fractures of the distal radius.[32-35] Only the study by Rozental and Blazar[34] listed associated injuries at the wrist level. The authors identified 4 patients (out of 18) with concomitant flexor tendon or neurovascular injuries that included radial or ulnar artery injury. In our experience, many open fractures of the distal radius are caused by an inside-out mechanism and present with an open wound either over the ulnar styloid or in the area of the ulnar side of the palmar radial metaphysis corresponding to the metaphyseal spike that mates with the sustentaculum lunatum (**Figures 5A, 5B**). Given these findings, we approach this intermediate column with particular care in cases of open fracture, paying attention to important structures (flexors, neurovascular) and looking for contamination from the environment into the fracture.

Fixation Techniques

The approach to fixation of partial articular palmar shear fractures is fairly straightforward. Buttress plate fixation has been well described and has had reliably good results.[36] However, in very distal fracture patterns and in cases in which the palmar lunate facet is fragmented as part of a complete articular fracture, a fragment-specific approach to fixation with or without spanning external fixation often is necessary.[37] The unrecognized sustentaculum lunatum fragment in comminuted complete articular fractures can lead to inadequate fixation constructs, resulting in loss of reduction and carpal subluxation in a palmar direction.[24,34,38]

Our surgical approach uses the standard anterior interval between the radial artery and the flexor carpi radialis, as described by Henry.[39] The flexor pollicis longus is retracted ulnarly, revealing the pronator quadratus. We then reflect the pronator qua-

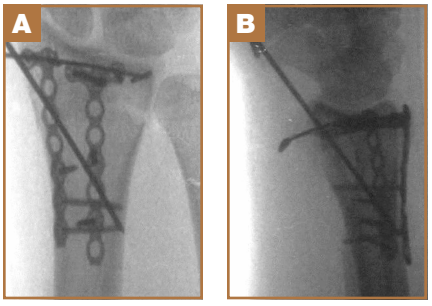

Figure 6. Intraoperative (A) anteroposterior and (B) lateral fluoroscopic views of fixation achieved by contouring miniplates (1.3 or 1.5 mm) to capture and buttress the sustentaculum lunatum.

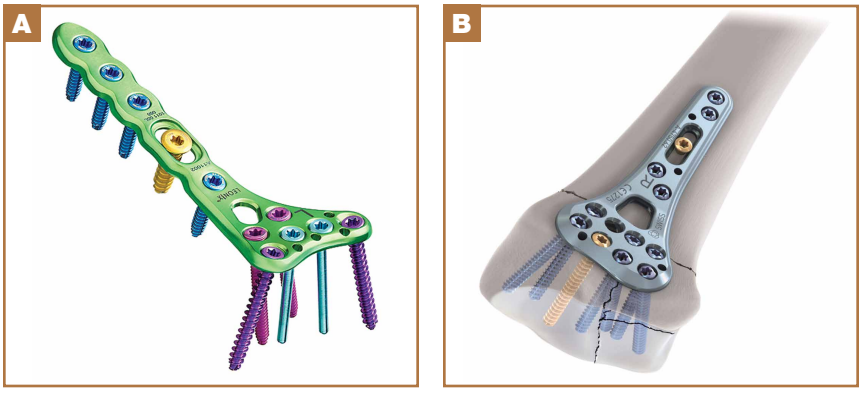

Figure 7. Distal radius plates with design features specifically targeting the lunate facet: (A) Leonix Axior Anatomic Volar and (B) Medartis Distal Radius 2.5 Adaptive. Figure 7A is reprinted with permission from Leonix. Figure 7B is reprinted with permission from Medartis.

dratus from the distal radial metaphysis until the most proximal and ulnar extent of the fracture is easily visualized. The palmar ulnar metaphyseal cortex that mates with the displaced sustentaculum lunatum is, in our experience, often the least comminuted portion of the metaphysis, thus providing a cortical key for restoration of height and alignment (Figures 5A, 5B). At our institution, fixation typically is achieved by contouring miniplates (1.3 or 1.5 mm) to capture and buttress the sustentaculum lunatum (**Figures 6A, 6B**). In our experience, the screw lengths in the most distal fixed-angle constructs at the palmar lip are limited to 6 mm or less to avoid penetration of the articular surface, though this has not been previously reported in the literature. After restoring the length and tilt of this intermediate column of the distal radius, we proceed with "rebuilding" the remainder of the fragments to our stabilized initial construct.

Various authors[40-43] have described alternative fixation methods for the palmar lunate facet fragment. Jupiter and Marent-Huber[42] described 2.4-mm locked-plate fixation with either a standard palmar plate or T- or L-plates for cases in which the palmar lip fragment is very distal and small. In fact, some newer anatomical distal radius implants include features designed to target these fragments (**Figures 7A, 7B**). An alternative fixation method involves use of a 26-gauge stainless steel wire passed through drill holes in the metaphysis 1 cm proximal to the fracture and then passed through the palmar capsule just distal to the fragment and secured in figure-8 fashion while the fragment is manually held reduced.[41] Still others have recommended limited internal fixation of the sustentaculum lunatum through an ulna-sided palmar approach to the distal radius (between the ulnar neurovascular bundle and the flexor tendons) combined with external fixation to restore length and palmar tilt in highly comminuted fractures.[40,43]

A method involving arthroscopically assisted reduction and fixation of the lunate facet has also been described, though this procedure is technically demanding and has limited indications.[44] It uses a Freer elevator passed through the standard 3-4 portal after initial visualization and evacuation of hematoma. The Freer elevator is used to disimpact the sustentaculum lunatum and to elevate it from its depressed position. With the dorsal lunate facet left displaced to facilitate access to the palmar fragment, a nerve hook retractor is used to reduce the palmar facet to the radial styloid, and Kirschner wires are used to achieve interfragmentary fixation. The dorsal lunate fragment is then pieced back to the articular segment, and the entire construct is fixed to the radial metaphysis with additional Kirschner wires.

Discussion

Given the increasing incidence of fractures of the distal radius, internal fixation of these injuries will continue to be relevant. American Academy of Orthopaedic Surgeons guidelines recommend operative fixation for fractures with postreduction radial shortening of more than 3 mm, dorsal tilt of more than 10°, or intra-articular displacement or step-off of more than 2 mm.[45] Dr. Eglseder and Dr. Pensy indicate operative treatment of any incongruity of more than 2 mm in a young, active adult with a fracture of the distal radius. For the multifragmentary distal radius being treated operatively, attempts are made to achieve reduction more accurate than this, but formal dorsal exposure or direct visualization of the joint surface via dorsal capsulotomy is carefully chosen based on age, activity level, and bone quality. Recent high-level evidence[46] showed that closed treatment of unstable fractures of the distal radius results in good outcomes in the elderly. However, it is important to note that fractures displaced in a palmar direction and palmar shear patterns were excluded from that work. It is widely accepted that palmar carpal translation should be addressed with internal fixation, and specific attention must therefore be paid to the lunate facet as the cornerstone of the distal radius. Furthermore, high-energy comminuted fractures in young patients still necessitate internal fixation of fragments to restore alignment and articular congruity.

Conclusion

The importance of the palmar lunate facet in providing support and restraint to palmar carpal translation and the key role of this facet in restoring the anatomy of the distal radius have been known. This fragment deserves special attention because fail-

ure to adequately stabilize it results in loss of fixation and carpal subluxation. Various approaches and fixation techniques have been recommended, including the method we prefer and have described here. Our newly proposed term, *sustentaculum lunatum*, our review of its structure and function, and our descriptions of fixation techniques are intended to promote awareness of this fragment in the treatment of fractures of the distal radius.

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References

1. Jupiter JB. Fractures of the distal end of the radius. *J Bone Joint Surg Am*. 1991;73(3):461-469.
2. Chung KC, Spilson SV. The frequency and epidemiology of hand and forearm fractures in the United States. *J Hand Surg Am*. 2001;26(5):908-915.
3. Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. *Hand Clin*. 2012;28(2):113-125.
4. 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):1868-1873.
5. Melone CP Jr. Articular fractures of the distal radius. *Orthop Clin North Am*. 1984;15(2):217-236.
6. Castaing J. Recent fractures of the lower extremity of the radius in adults [in French]. *Rev Chir Orthop Reparatrice Appar Mot*. 1964;50:581-696.
7. Frykman G. Fracture of the distal radius including sequelae—shoulder-hand-finger syndrome, disturbance in the distal radio-ulnar joint and impairment of nerve function. A clinical and experimental study. *Acta Orthop Scand*. 1967;(suppl 108):3+.
8. Isani A, Melone CP Jr. Classification and management of intra-articular fractures of the distal radius. *Hand Clin*. 1988;4(3):349-360.
9. Melone CP Jr. Distal radius fractures: patterns of articular fragmentation. *Orthop Clin North Am*. 1993;24(2):239-253.
10. Rettig ME, Dassa GL, Raskin KB, Melone CP Jr. Wrist fractures in the athlete: distal radius and carpal fractures. *Clin Sports Med*. 1998;17(3):469-489.
11. Müller ME, Koch P, Nazarian S, Schatzker J. *The Comprehensive Classification of Fractures of Long Bones*. Berlin, Germany: Springer-Verlag; 1990.
12. Peine R, Rikli DA, Hoffmann R, Duda G, Regazzoni P. Comparison of three different plating techniques for the dorsum of the distal radius: a biomechanical study. *J Hand Surg Am*. 2000;25(1):29-33.
13. Williams PL, Warwick R, Dyson M, Bannister LH, eds. *Gray's Anatomy*. 37th ed. New York, NY: Churchill Livingstone; 1989.
14. Linscheid RL. Kinematic considerations of the wrist. *Clin Orthop Relat Res*. 1986;(202):27-39.
15. Mekhail AO, Ebraheim NA, McCreath WA, Jackson WT, Yeasting RA. Anatomic and x-ray film studies of the distal articular surface of the radius. *J Hand Surg Am*. 1996;21(4):567-573.
16. Schuind FA, Linscheid RL, An KN, Chao EY. A normal data base of posteroanterior roentgenographic measurements of the wrist. *J Bone Joint Surg Am*. 1992;74(9):1418-1429.
17. Schuind F, Alemzadeh S, Stallenberg B, Burny F. Does the normal contralateral wrist provide the best reference for x-ray film measurements of the pathologic wrist? *J Hand Surg Am*. 1996;21(1):24-30.
18. Genda E, Horii E. Theoretical stress analysis in wrist joint: neutral position and functional position. *J Hand Surg Br*. 2000;25(3):292-295.
19. Giunta R, Löwer N, Wilhelm K, Keirse R, Rock C, Müller-Gerbl M. Altered patterns of subchondral bone mineralization in Kienböck's disease. *J Hand Surg Br*. 1997;22(1):16-20.
20. Andermahr J, Lozano-Calderon S, Trafton T, Crisco JJ, Ring D. The volar extension of the lunate facet of the distal radius: a quantitative anatomic study. *J Hand Surg Am*. 2006;31(6):892-895.
21. Bo WJ, Meschan I, Krueger WA. *Basic Atlas of Cross-Sectional Anatomy*. Philadelphia, PA: Saunders; 1980.
22. Cahill DR, Orland MJ, Miller GM. *Atlas of Human Cross-Sectional Anatomy: With CT and MR Images*. 3rd ed. New York, NY: Wiley; 1995.
23. El-Khoury GY, Bergman RA, Montgomery WJ. *Sectional Anatomy by MRI*. 2nd ed. New York, NY: Churchill Livingstone; 1995.
24. Harness NG, Jupiter JB, Orbay JL, Raskin KB, Fernandez DL. Loss of fixation of the volar lunate facet fragment in fractures of the distal part of the radius. *J Bone Joint Surg Am*. 2004;86(9):1900-1908.
25. Lewis OJ, Hamshere RJ, Bucknill TM. The anatomy of the wrist joint. *J Anat*. 1970;106(Pt 3):539-552.
26. Berger RA, Landsmeer JM. The palmar radiocarpal ligaments: a study of adult and fetal human wrist joints. *J Hand Surg Am*. 1990;15(6):847-854.
27. Apergis E, Darmanis S, Theodoratos G, Maris J. Beware of the ulno-palmar distal radial fragment. *J Hand Surg Br*. 2002;27(2):139-145.
28. Chang EY, Chen KC, Meunier MJ, Chung CB. Acute short radiolunate ligament rupture in a rock climber. *Skeletal Radiol*. 2014;43(2):235-238.
29. Souer JS, Wiggers J, Ring D. Quantitative 3-dimensional computed tomography measurement of volar shearing fractures of the distal radius. *J Hand Surg Am*. 2011;36(4):599-603.
30. Pruitt DL, Gilula LA, Manske PR, Vannier MW. Computed tomography scanning with image reconstruction in evaluation of distal radius fractures. *J Hand Surg Am*. 1994(5);19:720-727.
31. Goldwyn E, Pensy R, O'Toole RV, et al. Do traction radiographs of distal radial fractures influence fracture characterization and treatment? *J Bone Joint Surg Am*. 2012;94(22):2055-2062.
32. Glueck DA, Charoglu CP, Lawton JN. Factors associated with infection following open distal radius fractures. *Hand*. 2009;4(3):330-334.
33. Kurylo JC, Axelrad TW, Tornetta P 3rd, Jawa A. Open fractures of the distal radius: the effects of delayed debridement and immediate internal fixation on infection rates and the need for secondary procedures. *J Hand Surg Am*. 2011;36(7):1131-1134.
34. Rozental TD, Blazar PE. Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. *J Hand Surg Am*. 2006;31(3):359-365.
35. Rozental TD, Beredjiklian PK, Steinberg DR, Bozentka DJ. Open fractures of the distal radius. *J Hand Surg Am*. 2002;27(1):77-85.
36. Nana AD, Joshi A, Lichtman DM. Plating of the distal radius. *J Am Acad Orthop Surg*. 2005;13(3):159-171.
37. Bae DS, Koris MJ. Fragment-specific internal fixation of distal radius fractures. *Hand Clin*. 2005;21(3):355-362.
38. Berglund LM, Messer TM. Complications of volar plate fixation for managing distal radius fractures. *J Am Acad Orthop Surg*. 2009;17(6):369-377.
39. Henry AK. *Extensile Exposure*. 2nd ed. New York, NY: Churchill Livingstone; 1973.
40. Axelrod T, Paley D, Green J, McMurtry RY. Limited open reduction of the lunate facet in comminuted intra-articular fractures of the distal radius. *J Hand Surg Am*. 1988;13(3):372-377.
41. Chin KR, Jupiter JB. Wire-loop fixation of volar displaced osteochondral fractures of the distal radius. *J Hand Surg Am*. 1999;24(3):525-533.
42. Jupiter JB, Marent-Huber M; LCP Study Group. Operative management of distal radial fractures with 2.4-millimeter locking plates: a multicenter prospective case series. Surgical technique. *J Bone Joint Surg Am*. 2010;92(suppl 1, pt 1):96-106.
43. Ruch DS, Yang C, Smith BP. Results of palmar plating of the lunate facet combined with external fixation for the treatment of high-energy compression fractures of the distal radius. *J Orthop Trauma*. 2004;18(1):28-33.
44. Wiesler ER, Chloros GD, Lucas RM, Kuzma GR. Arthroscopic management of volar lunate facet fractures of the distal radius. *Tech Hand Up Extrem Surg*. 2006;10(3):139-144.
45. American Academy of Orthopaedic Surgeons. *The Treatment of Distal Radius Fractures: Guideline and Evidence Report*. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2009. http://www.aaos.org/research/guidelines/drfguideline.pdf. Accessed August 4, 2015.
46. Arora R, Lutz M, Deml C, Krappinger D, Haug L, Gabl M. A prospective randomized trial comparing nonoperative treatment with volar locking plate fixation for displaced and unstable distal radial fractures in patients sixty-five years of age and older. *J Bone Joint Surg Am*. 2011;93(23):2146-2153.

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