Loss of Fixation of the Volar Lunate Facet Fragment in Fractures of the Distal Part of the Radius

By Neil G. Harness, MD, Jesse B. Jupiter, MD, Jorge L. Orbay, MD, Keith B. Raskin, MD, and PD Dr. med Diego L. Fernandez

Investigation performed at the Department of Orthopaedic Surgery, Massachusetts General Hospital, Boston, Massachusetts; Miami Hand Center, Miami, Florida; Department of Orthopaedic Surgery, New York University-Hospital for Joint Diseases, New York City; and Department of Orthopaedic Surgery, Lindenhofspital, Bern, Switzerland

Background: The purpose of the present study is to report on a cohort of patients with a volar shearing fracture of the distal end of the radius in whom the unique anatomy of the distal cortical rim of the radius led to failure of support of a volar ulnar lunate facet fracture fragment.

Methods: Seven patients with a volar shearing fracture of the distal part of the radius who lost fixation of a volar lunate facet fragment with subsequent carpal displacement after open reduction and internal fixation were evaluated at an average of twenty-four months after surgery. One fracture was classified as B3.2 and six were classified as B3.3 according to the AO comprehensive classification system. All seven fractures initially were deemed to have an adequate reduction and internal fixation. Four patients required repeat open reduction and internal fixation, and one underwent a radiocarpal arthrodesis. At the time of the final follow-up, all patients were assessed with regard to their self-reported level of functioning and with use of Sarmiento's modification of the system of Gartland and Werley.

Results: At a mean of two years after the injury, six patients had returned to their previous level of function. The result was considered to be excellent for one patient, good for four, and fair for two. The average wrist extension was 48°, or 75% of that of the uninjured extremity. The average wrist flexion was 37°, or 64% of that of the uninjured extremity. The one patient who underwent radiocarpal arthrodesis had achievement of a solid union. The four patients who underwent repeat internal fixation had maintenance of reduction of the lunate facet fragment. The two patients who declined additional operative intervention had persistent dislocation of the carpus with the volar lunate facet fragment.

Conclusions: The stability of comminuted fractures of the distal part of the radius with volar fragmentation is determined not only by the reduction of the major fragments but also by the reduction of the small volar lunate fragment. The unique anatomy of this region may prevent standard fixation devices for distal radial fractures from supporting the entire volar surface effectively. It is preferable to recognize the complexity of the injury prior to the initial surgical intervention and to plan accordingly.

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

Displaced intra-articular fractures of the distal end of the radius represent complex injuries because of the small size of the fracture fragments and their interrelationship with radiocarpal and radioulnar kinematics[1-5]. While the morphology of the articular disruption may vary widely, it has become apparent that fractures involving the volar lunate facet articular fragment, as emphasized initially by Melone[1], are among the more difficult articular injuries to treat effectively. This difficulty is due, in part, to the normal anatomy of the volar aspect of the distal part of the radius. The volar surface of the distal part of the radius is relatively flat, except for the very distal margin, which slopes volarly to form a ridge from which the volar radiocarpal ligaments originate (Fig. 1). When viewed in the axial plane in cross-section, it is apparent that the distal cortical margin slopes volarly from radial to ulnar (Fig. 2)[6-10]. This, in turn, may prevent a volar-based fixation plate from providing equal support of both the scaphoid and lunate volar cortical margins.

The volar lunate fragment has been difficult to maintain in a reduced position when treated as an isolated fracture with a cast or splint[11-13] and when treated as part of a comminuted distal radial fracture[14,15]. To our knowledge, no

TABLE I Data on the Patients

Case	Gender, Age *(yr)*	Initial Treatment	AO Comprehensive Classification	Secondary Procedure	Bone Graft	Duration of Follow-up *(mo)*
1	F, 71	Volar T-plate	B3.3	—	No	28
2	F, 49	Volar T-plate	B3.3	—	No	12
3	M, 45	Volar T-plate/radial styloid cancellous screw	B3.3	Volar T-plate and ulnar-sided 4-hole 1/3 tubular plate	Yes	72
4	M, 54	Volar DVR plate	B3.2	Volar T-plate/radiocarpal external fixation	No	13
5	M, 48	Volar T-plate	B3.3	Volar T-plate/scapholunate repair	No	23
6	F, 38	Volar T-plate	B3.3	Radioscapholunate arthrodesis	No	18
7	M, 55	Volar DVR plate	B3.3	Volar lunate screw fixation/scapholunate repair	No	5

reports have documented loss of fixation of the lunate facet fragment after internal fixation of a volarly displaced shearing fracture of the distal part of the radius. The present report describes a series of seven patients who had a volar shearing fracture of the distal part of the radius that was characterized by two or more articular fragments and in whom standard volarly applied plates failed to support the realignment of a marginal lunate facet fracture fragment. This experience illustrates that, because of the unique anatomy of the very distal aspect of the volar part of the radius, standard distal radial implants may not support both the scaphoid and lunate facets equally well.

Materials and Methods

Over a ten-year period, in the combined practices of the authors, seven patients with a volar shearing fracture of the distal part of the radius that had been treated operatively with volar plate fixation demonstrated loss of reduction of a volar ulnar lunate facet fragment. The data on the patients were obtained by means of a retrospective review of the charts and plain radiographs under a protocol approved by the human research committee (Table I). The patients included four men and three women with an average age of 51.4 years (range, thirty-eight to seventy-one years). In four patients, the injury involved the dominant limb. Six patients were actively employed (as a chiropractor, gardener, lawyer, engineer, secretary, and interior decorator), and one was retired. Associated medical comorbidities included hypertension in three patients and rheumatoid arthritis in one.

Five fractures resulted from a fall from a standing height, one resulted from a sports-related injury, and one resulted from a motorcycle accident. Six fractures were classified as type B3.3 and one was classified as type B3.2 according to the AO comprehensive classification system[16]. Three patients had an associated ulnar styloid fracture, one of which was associated with a high-energy injury mechanism (a motorcycle accident). None of the patients with an ulnar styloid fracture had instability of the distal radioulnar joint. All of the fractures were closed.

The indication for the initial operation was an unacceptable closed reduction with volar displacement of the radiocarpal articulation. A standard AO/ASIF volar distal radius T-plate (Synthes, Paoli, Pennsylvania) was used in five patients, and a volar DVR locking plate (Hand Innovations, Miami, Florida) was used in two. In one patient, supplemental radial styloid fixation was obtained with a cancellous screw. None of the ulnar styloid fractures were treated operatively.

A retrospective review of the initial postoperative

Fig. 1

Sagittal computed tomographic scan demonstrating that the volar surface of the distal part of the radius slopes volarly to form a ridge from which the volar radiocarpal ligaments originate.

radiographs revealed an anatomic reduction of the volarly displaced fragments and radiocarpal articulation in each patient. In addition, there was acceptable placement of the implant volarly, with the distal part of the limb in line with the radial inclination of the distal part of the radius, in each patient. No patient was managed with a cast, and all patients began active motion within two weeks after surgery. Follow-up radiographs revealed loss of reduction of the volar lunate facet fragment in all seven patients and associated radiocarpal subluxation in four patients (Cases 1, 2, 4, and 5). While operative treatment was offered to all seven patients, two (Cases 1 and 2) declined additional intervention because they were relatively pain-free and did not object to the visible wrist deformity.

Five patients elected to undergo repeat surgery. The interval between the initial operative procedure and the reoperation varied widely, reflecting the fact that four of these patients were treated at an outside institution. The average time to reoperation was sixty days (range, nine to 146 days). By virtue of the duration of the time before presentation as well as associated findings at the time of surgery, a variety of reconstructive procedures were required. In four patients (Cases 3, 4, 5, and 7) the displaced lunate facet fragment could be reduced and supported with a new volarly applied plate or

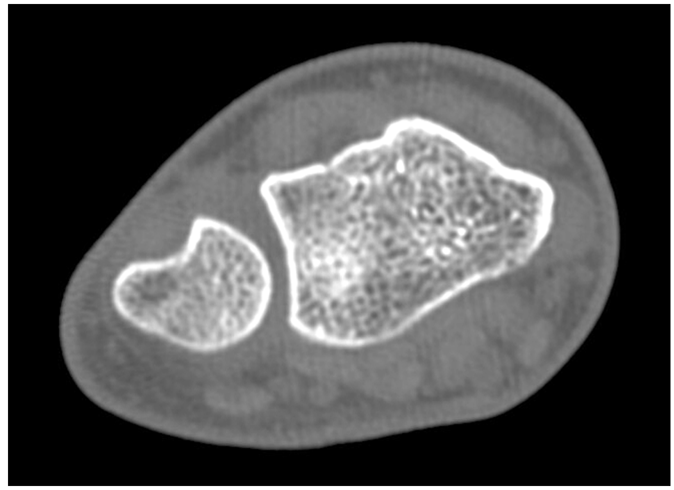

Fig. 2

Axial computed tomographic scan demonstrating that the distal cortical margin of the radius slopes volarly from radial to ulnar.

Fig. 3-A

Fig. 3-B

Figs. 3-A through 3-J Case 4, a fifty-four-year-old man who presented with a type-B3.2 volar shearing fracture of the distal part of the radius after a motorcycle accident. **Figs. 3-A and 3-B** Radiographs made at the time of presentation.

TABLE II Modified Gartland and Werley Score and Clinical Result

Case	Modified Gartland-Werley Score*	Clinical Result
1	6 (Good)	Works 40 hr/wk
2	8 (Good)	Occasional scar sensitivity, works without pain
3	2 (Excellent)	Occasional pain with exertion
4	7 (Good)	Same as preoperative status
5	16 (Fair)	Same as preoperative status
6	18 (Fair)	Daily activities/no chiropractic manipulations
7	8 (Good)	Full activities

*The score is given, in points, according to Sarmiento's modification[17] of the system of Gartland and Werley[18]. The corresponding rating of the score is given in parentheses.

screw. In two of these patients (Cases 5 and 7), a scapholunate dissociation also was noted and was treated operatively with direct ligament repair. In one patient (Case 4), additional external fixation was applied for eight weeks.

The last patient who was treated operatively (Case 6) had articular incongruity and an inability to maintain reduction of the radiocarpal articulation, which led to the decision to perform a radioscapholunate arthrodesis. One patient (Case 5) required removal of percutaneous Kirschner wires at eight weeks postoperatively, one patient (Case 6) required hardware removal after healing at the site of a radioscapholunate arthrodesis, and one patient (Case 7) underwent removal

Fig. 3-C

Fig. 3-D

Immediate postoperative radiographs demonstrating adequate initial capture of the volar lunate facet fragment with a volar DVR locking plate.

Fig. 3-E

Fig. 3-F

Radiographs, made five weeks postoperatively, demonstrating subsequent loss of fixation of the volar lunate facet fragment with volar dislocation of the carpus.

of a scapholunate screw four months after repair of the scapholunate interval. There were no infections or episodes of nerve dysfunction.

Evaluation

The final functional result was rated by the physician according to Sarmiento's modification[17] of the system described by Gartland and Werley[18]. The grip strength on the involved side was measured as the average of three attempts at maximal grip with a Jamar dynamometer (Asimow Engineering, Los Angeles, California) and was expressed as a percentage of that on the contralateral, uninvolved side. The final radiographs were evaluated by a single observer according to Sarmiento's modification[19] of the system of Lidstrom[20]. Radiographic signs of arthrosis were rated, according to the system of Knirk and Jupiter[3], as grade 0 (no arthritis), grade 1 (slight joint-space narrowing), grade 2 (marked joint-space narrowing, osteophyte formation), and grade 3 (bone-on-bone contact, osteophyte formation, cyst formation). Articular congruity was assessed according to the method of Knirk and Jupiter[3]. Step-off was classified as grade 0 (0 to 1 mm), grade 1 (1 to 2 mm), grade 2 (2 to 3 mm), or grade 3 (>3 mm).

Results

The average duration of follow-up was 24.4 months (range, five to seventy-two months). Six patients returned to their self-reported preoperative level of function. All patients but one returned to their previous level of employment and exercise capacity. One patient (Case 2) complained of occasional scar sensitivity but worked without pain. Another (Case 3) complained of occasional pain with heavy exertion. One patient (Case 6) who worked as a chiropractor did not have a return to full use of the wrist for manipulations after radioscapholunate arthrodesis.

Clinical Evaluation

The average wrist extension was 48° (range, 35° to 65°), or 75% of that of the uninjured extremity. The average wrist flexion was 37° (range, 20° to 50°), or 64% of that of the uninjured extremity. The average supination and pronation were 75° (range, 70° to 80°) and 75° (range, 65° to 80°), respectively. The average radial and ulnar deviation were 14° (range, 5° to 20°) and 15° (range, 5° to 30°), respectively.

The average grip strength was 29 kg (range, 18 to 40 kg) on the injured side, compared with 40 kg (range, 23 to 65 kg) on the uninjured side. The grip strength on the injured side

Fig. 3-G

Fig. 3-H

Radiographs made after the patient was managed with repeat internal fixation with use of a volar distal radial T-plate and a radiocarpal external fixator.

was an average of 77% (range, 62% to 96%) of that on the uninjured side.

When the five patients who underwent repeat internal fixation were compared with the two who were treated nonoperatively, no considerable difference was noted with regard to the range of motion of the wrist. In fact, the average flexion-extension arc for the two patients with persistent volar dislocation of the carpus was equal to the average arc for the entire group of patients. The grip strength, expressed as a percentage of that on the uninjured side, was 88% for these two patients compared with 71% for the patients who were treated operatively.

According to Sarmiento's modification[17] of the system of Gartland and Werley[18], the result was considered to be excellent for one patient, good for four, and fair for two (Cases 5 and 6). One of the fair results was in the patient (Case 6) who was managed with radiocarpal arthrodesis. In the subgroup of patients who required repeat internal fixation, one patient had an excellent result, two had a good result, and two had a fair result. The two patients who were treated nonoperatively had a good result (Table II).

Radiographic Assessment

Postoperatively, volar tilt averaged 11° (range, 6° to 18°), radial inclination averaged 21° (range, 18° to 25°), and ulnar variance averaged –0.4 mm (range, 3 to –3 mm). Two patients (Cases 1 and 2) who declined a second procedure had persistent dislocation and articulation of the carpus with the volar lunate facet fragment as well as the volar rim of the distal part of the radius.

In one patient (Case 6), union was achieved after radioscapholunate arthrodesis. In four other patients (Cases 3, 4, 5, and 7) reduction of the lunate facet fragment was maintained after repeat reduction and internal fixation. According to Sarmiento's modification[19] of the system of Lidstrom[20], the radiographic result was rated as excellent in three patients, good in one, and fair in two. According to the system of Knirk and Jupiter[3], radiographic signs of arthrosis were rated as grade 0 in one patient, grade 1 in three, and grade 2 in two. According to the method of Knirk and Jupiter[3], the articular congruity was classified as grade 0 (0 to 1 mm of step-off) in four patients (Cases 3, 4, 5, and 7) and as grade 1 (1-2 mm step-off) in two patients (Cases 1 and 2). One patient (Case 6) was not assessed with regard to the radiographic outcome because of the performance of a radiocarpal arthrodesis.

Illustrative Case Report

Case 4. A fifty-four-year-old man sustained a type-B3.2 volar

Fig. 3-I

Fig. 3-J

Follow-up radiographs, made seven months after the index procedure, showing healing of the fracture and maintenance of the reduction.

shearing injury with an associated ulnar styloid fracture (Figs. 3-A and 3-B). The fracture was stabilized with a volar DVR locking plate (Figs. 3-C and 3-D). After an apparently adequate initial reduction and fixation as determined on the basis of c-arm images made during the operation, the fixation of the volar lunate facet fragment was subsequently lost (Figs. 3-E and 3-F). The carpus dislocated with the fragment volar to the plate. The patient was managed, through a volar approach, with repeat reduction of the volar lunate facet fragment, application of a standard AO/ASIF volar distal radial plate, and placement of a bridging external fixator for additional stability (Figs. 3-G and 3-H). The external fixator was removed after eight weeks, and a good reduction was subsequently maintained (Figs. 3-I and 3-J). After thirteen months of follow-up, the modified Gartland and Werley rating[17,18] was good and the radiographic score was excellent.

Discussion

The experience described in the present report brings attention to the fact that, while the distal metaphyseal flare of the radius is flat and accommodates standard implants effectively, the very distal cortical margin is not the same when viewed in axial projections[6-10]. The ulnar volar margin of the lunate facet slopes volarly as viewed from proximal to distal and may not be effectively supported by standard implants. In addition, the volar rim of the distal part of the radius is not straight but slopes volarly from radial to ulnar[6-10]. This makes fractures of the volar margin of the distal part of the radius a challenge to treat[11-13,21].

On the basis of anatomic and radiographic studies, Mekhail et al.[22] described the profile of the volar margin of the distal part of the radius in the coronal plane as smooth, with a "lazy S" appearance. They found that the ulnar aspect of the volar rim of the radius is convex distally, forming a palmar prominence of the lunate facet. Paley et al.[23] attempted to accurately define the dorsal and volar edges of the distal part of the radius with use of anatomic and radiographic methods. They found that the volar rim of the distal part of the radius is more prominent toward the ulnar side at the volar prominence of the lunate facet and then it tapers off more radially. The volar lunate facet thus extends more distally than one would expect, which may make it more difficult to achieve adequate support with standard volar plate fixation. In addition, the volar aspect of the lunate fossa bears more load than the scaphoid fossa does when the wrist is in a position of function[24]. This force transmission across the volar margin of the lunate fossa may make it more difficult to control volar lunate fracture fragments with a volarly applied plate.

Anatomical studies by Berger and Landsmeer[25] demonstrated that the short radiolunate ligament originates from the volar margin of the lunate facet and attaches to the volar surface of the lunate. Based on its thickness, this ligament may play a key role in maintaining stability of the radiolunate articulation. A volar shearing fracture with comminution creates a functional radiolunate ligament avulsion, which may lead to instability.

In a previous study, two of us (J.B.J. and D.L.F.) and colleagues[26] demonstrated that the vast majority of volar shearing fractures have two or more articular components. The involvement of the ulnar marginal aspect of the lunate facet may not always be readily apparent on standard preoperative radiographs. Furthermore, the standard operative approach to these fractures has been through the distal limb of the Henry approach[27], which may limit adequate exposure to this region of the distal part of the radius. The deforming forces of the volar distal radioulnar ligament and ulnar radiocarpal ligaments, which attach to the ulnar volar lunate facet fragment, add to the risk of displacement if the fragment is not adequately supported.

The ability to effectively treat the fracture with realignment and stable fixation appears to be predicated on a number of factors. The amount of time that has transpired between the time of recognition and the time of repeat surgery will certainly be a factor. In addition, the size of the displaced fragment may require more than just support with the ulnar end of a T-shaped plate. Consideration should be given to additional support of the fragment with a tension-wire technique as described by Chin and Jupiter[14], with Kirschner wires left flush with the cortical rim and prominent on the dorsal side for later retrieval, with a radiolunate Kirschner wire, or with an external fixator[21].

In conclusion, when evaluating volar shearing fractures, one should heed the presence of a small ulnar lunate facet fragment. When standard radiographs reveal the possibility of such a fragment, two-dimensional and even three-dimensional computed tomographic scans may well provide important additional information preoperatively. Second, when faced with a more complex volar shearing fracture, the surgeon might consider an ulnarly-based incision between the ulnar artery and nerve and the flexor tendons to allow direct access to the volar ulnar corner of the radius[10]. Finally, adjuvant fixation of the fragment with a smaller implant placed more distally, or temporary external fixation, may prevent displacement of the volar lunate facet fragment. ■

Neil G. Harness, MD
Jesse B. Jupiter, MD
Department of Orthopaedic Surgery, Massachusetts General Hospital, Hand and Upper Extremity Service, 15 Parkman Street, ACC 527, Boston, MA 02114. E-mail address for J.B. Jupiter: jjupiter1@partners.org

Jorge L. Orbay, MD
Miami Hand Center and Hand Innovations, Inc., 8905 S.W. 87th Avenue, Suite 220, Miami, FL 33176

Keith B. Raskin, MD
New York University Medical Center, 317 East 34th Street, Third Floor, New York, NY 10016

PD Dr. med Diego L. Fernandez
Orthopadische Leitung, Lindenhofspital, Bremgartenstrasse 19, CH-3012 Bern, Switzerland

In support of their research or preparation of this manuscript, two of the authors (N.G.H. and J.B.J.) received research grant support from the AO Foundation. None of the authors received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

References

1. **Melone CP Jr.** Articular fractures of the distal radius. *Orthop Clin North Am.* 1984;15:217-36.
2. **Trumble TE, Schmitt SR, Vedder NB.** Factors affecting functional outcome of displaced intra-articular distal radius fractures. *J Hand Surg [Am].* 1994; 19:325-40.
3. **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.
4. **Catalano LW 3rd, 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;79:1290-302.
5. **Fernandez DL, Palmer AK.** Fractures of the distal radius. In: Green DP, Hotchkiss RN, Pederson WC, editors. *Green's operative hand surgery.* 4th ed. New York: Churchill Livingstone; 1999. p 929-85.
6. **Lewis OJ, Hamshere RJ, Bucknill TM.** The anatomy of the wrist joint. *J Anat.* 1970;106:539-52.
7. **El-Khoury GY, Bergman RA, Montgomery WJ.** *Sectional anatomy by MRI.* 2nd ed. New York: Churchill Livingstone; 1995. p 303-4.
8. **Cahill DR, Orland MJ, Miller GM.** *Atlas of human cross-sectional anatomy: with CT and MR images.* 3rd ed. New York: Wiley-Liss; 1995.
9. **Bo WJ, Meschan I, Krueger WA.** *Basic atlas of cross-sectional anatomy.* Philadelphia: Saunders; 1980. p 306-7.
10. **Gray H.** *Gray's anatomy.* Williams PL, Warwick R, Dyson M, Bannister LH, editors. 37th ed. New York: Churchill Livingstone; 1989. p 414.
11. **Apergis E, Darmanis S, Theodoratos G, Maris J.** Beware of the ulno-palmar distal radial fragment. *J Hand Surg [Br].* 2002;27:139-45.
12. **Thomsen S, Falstie-Jensen S.** Palmar dislocation of the radiocarpal joint. *J Hand Surg [Am].* 1989;14:627-30.
13. **Bellinghausen HW, Gilula LA, Young LV, Weeks PM.** Post-traumatic palmar carpal subluxation. Report of two cases. *J Bone Joint Surg Am.* 1983;65:998-1006.
14. **Chin KR, Jupiter JB.** Wire-loop fixation of volar displaced osteochondral fractures of the distal radius. *J Hand Surg [Am].* 1999;24:525-33.
15. **Takami H, Takahashi S, Ando M.** Comminuted intra-articular fracture of the distal radius with rotation of the palmar medial articular fragment: case reports. *J Trauma.* 1992;32:404-7.
16. **Muller ME, Nazarian S, Koch P, Schaftzken J.** *The comprehensive classification of fractures of long bones.* New York: Springer; 1990.
17. **Sarmiento A, Pratt GW, Berry NC, Sinclair WF.** Colles' fractures. Functional bracing in supination. *J Bone Joint Surg Am.* 1975;57:311-7.
18. **Gartland JJ Jr, Werley CW.** Evaluation of healed Colles' fractures. *J Bone Joint Surg Am.* 1951;33:895-907.

19. **Sarmiento A, Zagorski JB, Sinclair WF.** Functional bracing of Colles' fractures: a prospective study of immobilization in supination vs. pronation. *Clin Orthop.* 1980;146:175-83.

20. **Lidstrom A.** Fractures of the distal end of the radius. A clinical and statistical study of end results. *Acta Orthop Scand.* 1959;Suppl 41:1-118.

21. **Smith RS, Crick JC, Alonso J, Horowitz M.** Open reduction and internal fixation of volar lip fractures of the distal radius. *J Orthop Trauma.* 1988;2:181-7.

22. **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;21:567-73.

23. **Paley D, Axelrod TS, Martin C, Rubenstein J, McMurtry RY.** Radiographic definition of the dorsal and palmar edges of the distal radius. *J Hand Surg [Am].* 1989;14:272-6.

24. **Genda E, Horii E.** Theoretical stress analysis in wrist joint—neutral position and functional position. *J Hand Surg [Br].* 2000;25:292-5.

25. **Berger RA, Landsmeer JM.** The palmar radiocarpal ligaments: a study of adult and fetal human wrist joints. *J Hand Surg [Am].* 1990;15:847-54.

26. **Jupiter JB, Fernandez DL, Toh CL, Fellman T, Ring D.** Operative treatment of volar intra-articular fractures of the distal end of the radius. *J Bone Joint Surg Am.* 1996;78:1817-28.

27. **Henry AK.** *Extensile exposure.* 2nd ed. New York: Churchill Livingstone; 1973.