Acta Orthop. Belg., 2020, **86 e-SUPPLEMENT** 1, 101-108

ORIGINAL STUDY

Outcomes of dorsal plating for selected distal radius fractures

Nader PAKSIMA, Adam DRIESMAN, Julie JOHNSON, Christopher KIM, Kenneth EGOL

From the NYU Hospital for Joint Disease, New York, USA

To determine the functional outcome and complications following dorsal plating for unstable fractures of the distal radius.
We searched our IRB-approved Distal Radius Fracture Databases and identified all patients who were treated with a dorsally applied plate. Thirty-four distal radius fractures in 33 patients with a mean age of 50 years and average follow-up of 14 months were treated with a dorsal locking plate from 2007 to 2015.
Fifteen and six patients had dorsal shearing fracture pattern and delayed presentation, respectively. There were no loss of reduction, malunion, or nonunion. Average VAS pain score was 2.1/10. Eight patients (23%) required hardware removal, one of which was due to extensor tendon rupture (3%) and five due to extensor tendon irritation (15%).
Dorsal locked plating of distal radius fractures with newer low-profile implants is a viable option for particular fractures types, such as the dorsal rim shear type fractures.

Keywords: Complications ; distal radius ; dorsal plate ; fracture ; operative repair.

INTRODUCTION

There has been a significant trend towards operative repair of distal radius fractures in recent years. The use of locked volar plates has increased significantly and is now the predominant method for fixation of displaced distal radius fractures *(3)*. The locked volar plate offers significant biomechanical advantages and is associated with good clinical outcomes and high patient satisfaction *(13,14)*. Historically, dorsally applied plates such as the oblique T plate, for distal radius fractures were performed with the use of thicker non-contoured implants in an area with little soft tissue coverage. While the use of the dorsal buttress plate made good biomechanical sense, the associated extensor tendon complications tempered the use of this technique *(20)*. The Pi-plate (Synthes, Paoli, PA) was the first generation of dorsal locking plates to be introduced. This plate construct offered the advantage of a fixed

■ Nader Paksima[1], DO, MPH.
■ Adam Driesman[1], MD.
■ Julie Johnson[2], MD.
■ Christopher Kim[3], Pharm. D.
■ Kenneth Egol[1], MD.
[1]*NYU Langone Orthopedic Hospital, Department of Orthopaedic Surgery;* [2]*University of Pittsburgh, Department of Orthopaedic Surgery;* [3]*Rutgers University, Robert Wood Johnson Medical School*.
Correspondence: Adam DRIESMAN, New York University Hospital for Joint Diseases, Department of Orthopaedic Surgery, 530 First Avenue, Suite 8U, New York, NY 10016, Phone: (212)263-2192, Fax: (212)263-0231
E-mail : adam.driesman@gmail.com

Level of evidence: Treatment Benefits Level IV. Conflict of interest: All authors declare that they have not received any funding or other benefits in support of this study. No relevant financial relationships to disclose.

angle device which would buttress the metaphyseal and articular displacement, and provide stable internal fixation of displaced distal radius fractures and dorsal rim shear fractures *(15)*. By buttressing the dorsal shear fracture and the subchondral bone the plate directly stabilized the fracture's tendency to fall back into dorsal angulation. Still, upwards of 20% of patients reported extensor tendons problem with the use of the device and enthusiasm for dorsal locked plating declined *(8,18,20)*.

More recently, lower-profile (1.5mm in thickness) precontoured locked titanium plates have been developed to try to address the extensor tendon issues associated with dorsally applied locked plates *(7,4)*. Currently there is paucity of literature regarding outcomes with the use of these lower profile, locked dorsal titanium plates. In this study we report a series of displaced distal radius intraarticular fractures treated by a two surgeons using a low-profile titanium locked dorsal plate. Rather than directing comparing this technique with other methods of surgical fixation, we hope to examine if dorsal plating is a safe and effective alternative for specific fracture types and indications (ie. dorsal shear and late presenting fractures).

MATERIALS AND METHODS

This study was approved by our institutional review board. Between October 2004 and November 2015 more than 800 patients who sustained a distal radial fracture presented to our institution. This population was retrospectively examined and all patients who were treated with a dorsal locking plate were extracted for this study. The indications for use of a dorsal locking plate were significant dorsal comminution, delayed presentation, dorsal shear fractures and/or concomitant carpal injuries (Figure 1). Another indication was for those fractures that presented with dorsal angulation between 4 and 6 weeks post trauma and required takedown of the immature callous. Our first use of a dorsal locking plate was in 2007. Forty patients with a total of 41 distal radial fractures were identified. Exclusion criteria included age less than 18 years, less than 3 months of follow up, incomplete radiographic follow up, and any other concomitant fixation of the distal radius with the exception of Kirschner wires (K-wires). Thirty-three patients with a total of 34 distal radial fractures met inclusion criteria.

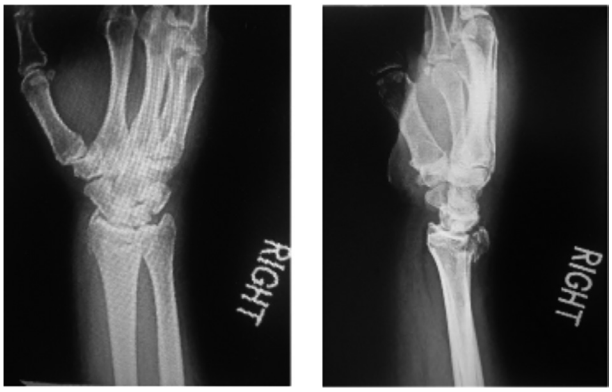

Fig. 1. — Oblique and Lateral Wrist X-rays showing examples of AO type B sheer fracture that was indicated for lower-profile dorsal plating

Author's Preferred Surgical Technique

A 10 cm dorsal incision is centered over Lister's tubercle extending 1 cm distal to the radiocarpal joint and going proximal approximately 9 cm. The skin and subcutaneous tissues are incised with care taken to protect the superficial branch of the radial nerve. The extensor retinaculum is exposed and two flaps of the extensor retinaculum are made; one based ulnarly and the other radially. The ulnar based flap was created from the distal part of the retinaculum, it starts between the first and second dorsal compartments, followed by elevation of the 2nd, 3rd, and 4th compartments. The radial based flap start over the 5th compartment, followed by elevation of 4th, 3rd and 2nd compartments. By elevating the two flaps, like a drawbridge, the tendons are completely mobilized and the fracture site is exposed. Prior to making the flaps, the plate is used to judge its position on the distal radius and to confirm that one of the flaps will cover most of the screwholes (Figure 2). The purpose of the flaps is for one limb to cover the distal row of screws and one to prevent potential bow stringing of the extensor tendons.

Next, the periosteum of the distal radius is incised and the fracture is exposed. An arthrotomy can be made if needed and a direct open reduction of the articular fragments is performed. The fracture

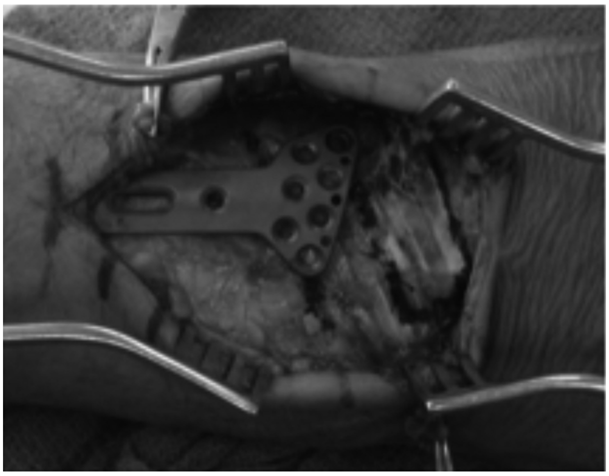

Fig. 2. — The plate is used to judge its position on the distal radius

is then reduced and stabilized with typically three temporary Kirschner wires (Zebra 1.1 mm k wires) *(23)* placed as distal as possible in order to engage the dorsal rim of the radius, and to get a bi-cortical fixation by engaging the volar metaphyseal portion of the radius. By placing the K-wires as distal as possible, the plate can be placed on the dorsal rim distal radius without impinging on the carpus with extension (Figure 3). If Lister's tubercle was not already fractured, it is removed using a rongeur so that the dorsal aspect of the radius has a flatter contour allowing the plate a better fit. The metaphyseal defect is assessed and if indicated bone grafting or synthetic bone void filler material can be placed. In fractures that are a few weeks old, the nascent metaphyseal callous can be used as local bone graft. The plate is fixed to the radial shaft using an oblong hole, which allows for small adjustments to be made to its position. Often, the plate will need to be contoured to fit the shape of the dorsal surface and be less prominent. The thin titanium plate is easily contoured while maintaining the locking capabilities. Once the plate position on the shaft is confirmed, the locking pegs or bicortical screws are placed in the distal segment.

When reviewing radiographs of the dorsally-placed distal radius plate, it is important to remember that the dorsal rim of the radius extends more distal than the proximal rim on the PA radiograph. Therefore, the plate will appear to be distal to the articular surface when placed. This will be evident

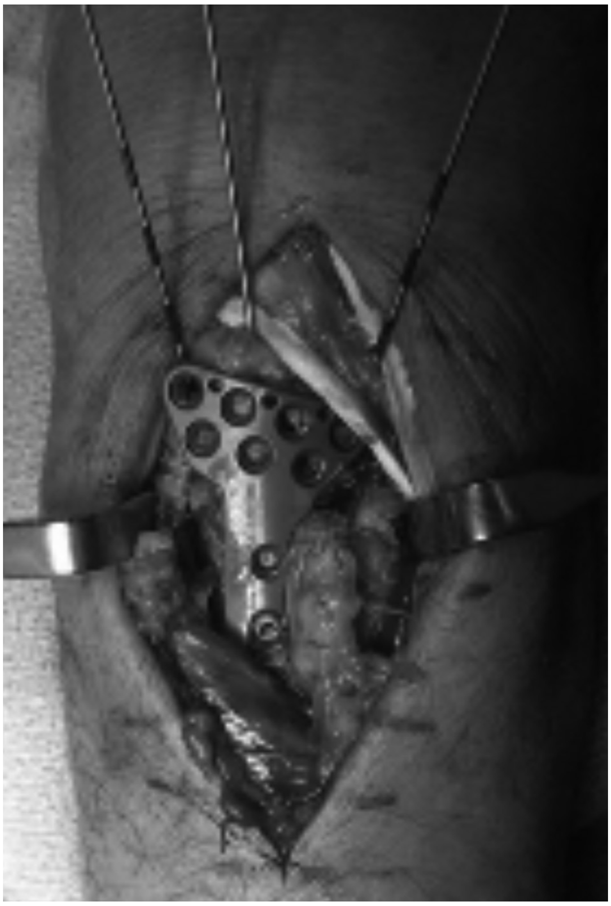

Fig. 3. — Placing the K-wires as distal as possible allows the plate to be placed on the distal radius

on the lateral view, where the dorsal rim and the distal extent of the plate are easily identified. A specialized PA radiograph can be obtained with the beam directed at 10 degrees to the plane of the forearm , along the articular surface to demonstrate that the joint is free of penetration (Figure 4). Since the K-wires were placed on the dorsal rim, the plate can be placed as distally as the K-wires allow with confidence that it will not impinge on the lunate with dorsiflexion of the wrist. The distal row of pegs should be placed with some degree of proximal angulation to avoid joint penetration. The distal row can also be left empty and used as a buttress plate and the proximal row can be filled to stabilize the distal fragment without risking joint penetration.

Following completion of the fixation, the temporary K-wires are removed and the retinacular

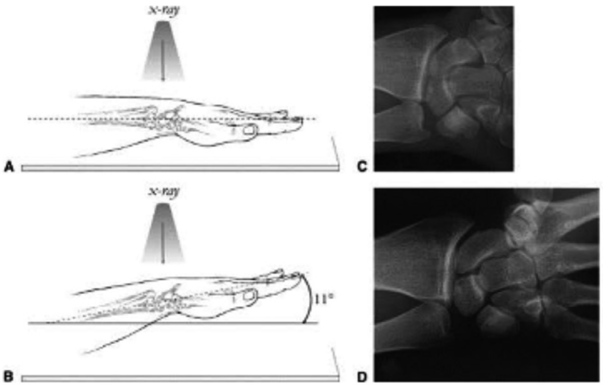

Fig. 4. — A specialized PA radiograph can be obtained with the beam directed at 10 degrees to the plane of the forearm (Boyer et al. 2004)

flaps are closed. One retinacular flap goes over the plate and under the tendons to protect the tendons, and the second flap is used to prevent bow stringing by going over the tendons before being sutured to the rim of retinaculum. The tourniquet is let down, hemostasis is achieved, and layered closure is performed. Bulky dressings and a short arm plaster volar splint was applied.

Outcomes Evaluation

All patients were seen postoperatively by their treating surgeon (NP and KE), and all data was collected from the medical record by an independent, trained researcher. All patients were switched to a removable wrist support from one week to six weeks post fixation and participated in a formal outpatient therapy program, which emphasized active and passive range of finger, wrist, and forearm motion. Patients were restricted to carry no more than 5 lbs until fracture union. Follow-up examinations conducted at three, six, twelve, twenty-four, and thirty-six months included measurements of wrist and finger range of motion, grip strength measured with a Jamar dynamometer (Lafayette Instrument Company, Lafayette, IN), and functional outcome measured with use of the Quick DASH questionnaire (0 to 100, lower score indicates better function) *(6)*. Pain was rated with use of a 10-point visual analog scale, with 0 indicating no pain. Complications such as wound infection, pin tract infection, carpal tunnel syndrome, nerve deficits, reflex sympathetic dystrophy, tendonitis, tendon rupture, loss of reduction, hardware failure, or return to the operating room were prospectively recorded for each case. Removal of hardware was noted for each case.

Radiographic outcome with regard to fracture union, loss of reduction, and development of arthritis was assessed at each visit. Measurements of radial inclination, radial height, tilt, ulnar variance, and articular step-off were made on each radiograph by a trained research associate under the direction of the treating surgeon. Arthritic change or its advancement was noted if present and was scored according to the OA grading scale *(9)*.

RESULTS

There were 18 males and 15 females in this study with a mean age of 50.5 years (range 19 to 78 years) (Table I). The average time to follow up was 14 months (range 3 to 48 months). All patients had radiographs with adequate fracture healing. Hand dominance was not recorded in two patients. Six patients had a delayed presentation greater than 4 weeks. Our patient population included 17 (50%) AO Type B fractures, 15 of which were dorsal shear type of fractures (Figure 1). We also had 10 Type C intraarticular displaced fractures and seven Type A extraarticular comminuted fractures (Table II). Seven patients had concomitant fractures of the carpus and eleven had concomitant fractures of the ulna. Four patients had carpal tunnel releases at the time of surgery. Fifteen fractures were treated with supplemental bone grafting at the time of dorsal plating; 13 had synthetic calcium phosphate (HydroSet, Stryker, Mahwah, NJ), and 2 only had autograft using local callous. The remaining 13 patients did not have any form of bone grafting.

All fractures united. Radiographic measurements were taken after union had been achieved (Table III). Only three patients had intraarticular step off of ≥1mm; all others healed with 0 mm of intraarticular step off. At longest follow up, twenty three patients (68%) had an OA grading of zero, seven (21%) had an OA grading of 1, and four patients (12%) had an OA grading of 2.

The average pain at final follow up rated on a visual analog pain scale from 0-10, with 0 being

Table I. — Demographics

Mean age (years)	51 ± 18
Gender Male Female	 18 (55%) 15 (45%)
Handedness Right Left	 26 (79%) 6 (18%)
Wrist fractured Dominant Nondominant Bilateral	 17 (52%) 13 (30%) 1 (3%)
Mechanism Motor vehicle accident Crush Fall from standing Fall from height Other	 5 (15%) 3 (9%) 16 (47%) 6 (18%) 4 (12%)
Mean duration of follow-up (months)	14 ± 12

Table II. — AO fracture classification

AO Fracture Classification		n(%)
Extra Articular		7
	A2.1	2 (6%)
	A2.2	1 (3%)
	A3.1	2 (6%)
	A3.2	1 (3%)
	A3.3	1 (3%)
Partially Articular		17
	B2.1	4 (12%)
	B2.2	1 (3%)
	B2.3	10 (30%)
	B3.1	2 (6%)
Complete Articular		10
	C1.1	1 (3%)
	C1.2	3 (9%)
	C2.1	1 (3%)
	C2.3	1 (3%)
	C3.1	2 (6%)

Table III. — Final Post Op Measurements

Radiographic parameter	Average ± SD (range)
Volar tilt (deg)	9.1 ± 8.9 (-9 to 23)
Radial inclination (deg)	20.5 ± 4.3 (12 to 30)
Radial height (mm)	11.3 ± 2.8 (7 to 17)
Step off (mm)	0.13 ± 0.4 (0 to 1.8)
Ulnar variance (mm)	2.4 ± 2.0 (0 to 6)
OA Grading	0.5 ± 0.8 (0 to 2)
Range of Motion	Average ± SD (range)
Extension	43.4 ± 14.3 (10-70)
Flexion	44.4 ± 18.5 (15-90)
Ulnar deviation	21.1 ± 8.5 (10-35)
Radial deviation	12.3 ± 8.7 (0-28)
Supination	75.5 ± 13.4 (40-90)
Pronation	77.4 ± 11.4 (40-90)

no pain, was 2.1±1.7 (range 0-5). Patient-reported complications include pain, tendon irritation, and decreased range of motion. Seven patients reported pain as a complication, four reported wrist stiffness, and one reported decreased ability to supinate the forearm. Range of motion was taken at longest follow up (Table III). The average Quick DASH score at longest follow up was 34.6 ± 25.

Eight patients (23.5%) required removal of a plate: five for tendon irritation, one after a tendon rupture and two for limited ROM. One of the patients with decreased ROM had his dorsal plate removed at 6 months after CT scan revealed that the dorsal ulnar corner of the plate was hindering supination. The patient who sustained tendon rupture originally present with irritation at 4 years after the initial injury, but intraoperatively it was noted to have rupture of the EIP. Therefore, a tendon transfer of the EIP to the EDC was carried out.

DISCUSSION

The American Academy of Orthopedic Surgeons published their guidelines and evidence report for the treatment of distal radius fractures. As robust evidence was unavailable, they were unable to recommend a specific operative treatment *(11)*. Given the paucity of clear consensus regarding treatment of displaced distal radius fractures, surgeons often use their best judgment and choose approaches that make biomechanical sense. Despite the shift towards volar locked plating for surgically-indicated distal radius fractures, we believe there are a subset of patients who are best treated with dorsally applied plate and screws.

Dorsal plates were initially used for the operative treatment of distal radius fractures; however, problems with soft tissue coverage as well as irritation of extensor tendons resulted in this technique being abandoned *(20)*. Later, with the advent of locked volar plating, enthusiasm for internal fixation of distal radius fractures with plates and screws returned *(21)*. For dorsally displaced distal radius fractures it makes biomechanical sense to utilize dorsal instead of volar plating as they will directly stabilize the fracture's tendency to fall back into dorsal angulation.

There are a number of theoretical benefits inherent to dorsal plating. A dorsal approach to the distal radius is straight forward and dissection is easily accomplished. The dorsal approach offers an opportunity to make an arthrotomy and directly view the articular surface *(20)*. An arthrotomy is ill-advised using the volar approach; instead, indirect and fluoroscopic techniques have to be used to determine the quality of the reduction. The ability to perform an arthrotomy is also advantageous as it facilitates the treatment of concomitant carpal injuries such as scaphoid fractures and ligament tears. The dorsal approach also allows for dorsal bone grafting to be performed at the metaphyseal defect. This is more important in fractures that are several weeks old, and in osteoporotic bone that might have limited healing potential. When patients present for treatment between the fourth and sixth week, there is typically abundant nascent callus formation dorsally. A dorsal approach allows the callus to be harvested for bone graft, and allows for easier correction of the malunion (Figure 5). Another potential advantage of the dorsal approach is that the posterior interosseous nerve can be identified and resected; by partially denervating the wrist, there may be a decrease in postoperative pain levels. All the potential advantages stated above, however, are theoretical and the real question is whether they will translate into better results for actual patients. If the complications typically associated with dorsal plates could be avoided with a low-profile locked implant, these plates could be very practical.

Fig. 5. — AP and Lateral Wrist X-rays showing examples of nascent malunions that was indicated for lower-profile dorsal plating

We are presenting a retrospective case series of displaced distal radius fractures treated with a dorsal approach using a low-profile locked titanium plate. The results obtained in this case series, while comparable, are still inferior to case series of patients treated with both locked volar plates as well as with external fixation *(16,17)*. Ideally, the dorsal plate is best suited for treatment of dorsal shear fractures, which the volar plate has a difficult time addressing. Dorsal shear, dorsal rim, and dorsal/ulnar die-punch fractures are difficult to control from the volar side. In order to control them from the volar side, a bicortical screw must be used. Bicortical screws protrude dorsally and have the potential to cause tendon irritation. A dorsally applied plate for dorsal shear fractures acts as a buttress device and potentially avoids tendon irritation while biomechanically giving superior fixation of the dorsal rim fractures.

A concern about using a dorsal plate is that the hardware is prominent and will require removal. In our series, eight patients (23%) required removal of the plates. One removal of hardware was due to a technical error, in which the plate was placed too ulnarly and impinged on the distal radioulnar joint. In the second case, the plate was removed because the patient developed nonunion of scaphoid and capitate fractures (scaphocapitate syndrome, with the fracture line in each bone is in direction continuation *(5,10)*) and required a second surgery for treatment of the carpal nonunion; the hardware was removed as part of the second surgery. Five of the cases were due to the extensor tendon irritation and painful hardware, with all patients had resolving pain after intervention. The last case of EIP tendon rupture occurred 46 months after the initial injury and fixation. While this 23% hardware removal rate is greater than found in volar plating *(12)*, it does compares favorably to case series of other dorsal locked plates. Previous studies looking at the rate of tendon irritation and plate removal have had similar findings. Ring et al described the series of 22 patients treated with a Synthes Pi plate and 23% developed extensor tendonitis and 18% required plate removal *(15)*. Simic et al reported on 60 distal radius fractures treated with low-profile non-locked dorsal plate and there was 2% incidence of tendon irritation requiring plate removal *(19)*. Yu et al reported on two groups of patients treated with dorsal nonlocking plates versus volar locked plates. He found that 3 of 57 (6%) dorsal nonlocking plates were removed due to complications and 9 of 57 (16%) had hardware discomfort, tendon irritation or rupture. Contrasting that to volar plates, 4 of 47 (8.5%) volar locking plates needed to be removed and 7 of 47 (15%) patients had hardware discomfort, tendon irritation or rupture *(22)*. When comparing the incidence of hardware removal to locked volar plating, Arora et al reported that 9 of 36 patients had either flexor or extensor tendon problems that required hardware removal (25%) with the use of volar locked plate *(1)*.

One limitation of this study is that it does not directly compare dorsal locked plating with other methods of surgical fixation. This is because we chose to use dorsal plating for specific indications (dorsal shear, late presentation, concomitent carpal injuries), the dorsal plate technique was used in only 4% of the distal radius fractures we took care off during the study period With regards to radiographic and range of motion parameters, the results we obtained are comparable to previously published studies on volar plates *(1,22)*. The Quick DASH scores obtained in our study were higher than those in previously published studies, which may be due to the large number of concomitant injuries in our patient population. Other limitations include short follow-up and low number of patients. A prospective, randomized study would be the next best step in order to more accurately compare these methods of fixation. This would give a more precise description and better comparison of the outcomes of dorsal plating.

In conclusion, dorsal locked plating of distal radius fractures with newer low-profile implants still deserves a place in the armamentarium for some particular fractures types, such as the dorsal rim shear type fractures. The outcomes were comparable to other techniques, however associated complications are still slightly greater than with volar locked plating.

CONCLUSION

The purpose of this retrospective study was to evaluate clinical and radiological results of all levels plate fixations compared with alternating levels plate fixation in open door cervical laminoplasty for treatment of degenerative cervical myelopathy.

REFERENCES

1. **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 7 ; 93 : 2146-53.
2. **Boyer MI, Korcek KJ, Gelberman RH, Gilula LA, Ditsios K, Evanoff BA.** Anatomic Tilt X-Rays of the Distal Radius: An Ex Vivo Analysis of Surgical Fixation. *J Hand Surg Am.* 2004 ; 29 : 116-22.
3. **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 ; 191:1868-73.
4. **Day CS, Franko OI.** Low-profile dorsal plating for dorsally angulated distal radius fractures. *Tech Hand Up Extrem Surg* 2007 ; 11 : 142-8.
5. **Fenton RL.** The Naviculo-Capitate Fracture Syndrome. *J Bone Jt Surg.* 1956 ; 38 :681-4.

6. **Hudak PL, Amadio PC, Bombardier C.** Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med.* 1996 ; 29 : 602-8.
7. **Kamath AF, Zurakowski D, Day CS.** Low-profile dorsal plating for dorsally angulated distal radius fractures: an outcomes study. *J Hand Surg Am.* 2006 ; 31 :1061-7.
8. **Kambouroglou GK, Axelrod TS.** Complications of the AO/ASIF titanium distal radius plate system (pi plate) in internal fixation of the distal radius: a brief report. *J Hand Surg Am.* 1998 ; 2 3 :737-41.
9. **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.
10. **Kumar A, Thomas AP.** Scapho-capitate fracture syndrome a case report. *Acta Orthop Belg.* 2001 ; 67 : 185-9.
11. **Lichtman DM, Bindra RR, Boyer MI, Putnam MD, Ring D, Slutsky DJ** *et al.* American Academy of Orthopaedic Surgeons clinical practice guideline on: the treatment of distal radius fractures. *J Bone Joint Surg Am.* 2011 ; 20 ; 93 : 775–8.
12. **Lutsky KF, Beredjiklian PK, Hioe S, Bilello J, Kim N, Matzon JL.** Incidence of hardware removal following volar plate fixation of distal radius fracture. *J Hand Surg Am.* 2015 ; 40 : 2410-5.
13. **Musgrave DS, Idler RS.** Volar fixation of dorsally displaced distal radius fractures using the 2.4-mm locking compression plates. *J Hand Surg Am.* 2005 ; 30 : 743-9.
14. **Orbay JL, Fernandez DL.** Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. *J Hand Surg Am.* 2002 ; 27 :205-15.
15. **Ring D, Jupiter JB, Brennwald J, Büchler U, Hastings H.** Prospective multicenter trial of a plate for dorsal fixation of distal radius fractures. *J Hand Surg Am.* 1997 ; 22 : 777-84.
16. **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 : 359-65.
17. **Rozental TD, Blazar PE, Franko OI, Chacko AT, Earp BE, Day CS.** Functional outcomes for unstable distal radial fractures treated with open reduction and internal fixation or closed reduction and percutaneous fixation. A prospective randomized trial. *J Bone Joint Surg Am.* 2009 ; 91 : 1837-46.
18. **Schnur DP, Chang B.** Extensor tendon rupture after internal fixation of a distal radius fracture using a dorsally placed AO/ASIF titanium pi plate. Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation. *Ann Plast Surg.* 2000 ; 44 : 564-6.
19. **Simic PM, Robison J, Gardner MJ, Gelberman RH, Weiland AJ, Boyer MI.** Treatment of distal radius fractures with a low-profile dorsal plating system: an outcomes assessment. *J Hand Surg Am.* 2006 ; 31 : 382-6.
20. **Tavakolian JD, Jupiter JB.** Dorsal plating for distal radius fractures. Vol. 21, *Hand Clinics.* 2005 ; 341-6.
21. **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.
22. **Yu YR, Makhni MC, Tabrizi S, Rozental TD, Mundanthanam G, Day CS.** Complications of low-profile dorsal versus volar locking plates in the distal radius: A comparative study. *J Hand Surg Am.* 2011 ; 36 : 1135-41.
23. **Stryker** - Medical Devices & Equipment Manufacturing Company : Stryker [Internet]. [cited 2016 Apr 12]. Available from: http://www.stryker.com/en-us/index.htm