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Volar hook plate stabilization of volar marginal fragments in intra-articular distal radius fractures

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ABSTRACT

Background: : In the setting of intra-articular distal radius fractures, the volar lunate facet (VLF) is the only articular segment that resists volar carpal subluxation. So, it is important to achieve a stable fixation of this key fragment. The VLF, when small (also called as volar marginal fragment, VMF) is located distal to the watershed line making fixation with the conventional volar locking plates difficult or impossible.
Methods: : 18 patients with either an AO: 2R3B3 or a C3 fracture consisting of a VMF underwent surgical repair through a volar approach. The VMF was stabilised using a anatomical volar hook plate. Remaining fracture components were stabilised using 2.4/ 2.0 mm locked plates. Fracture healing, ability of the hook plate to maintain reduction of the VMF and complications were assessed during follow up. Functional outcome was evaluated using Mayo score and patient rated wrist evaluation questionnaires.
Results: : All fractures united at follow up. Reduction of the VMF was maintained through healing with a stable radiocarpal and distal radioulnar joint. The mean flexion - extension wrist arc was 105° ± 10.2° The mean grip strength reached 74.6 ± 6% of the opposite side. The mean Mayo wrist score was 75 ± 5.3 and the mean patient rated wrist evaluation (PRWE) score was 15.2 ± 4.3 indicating recovery of wrist function.
Conclusion: : It is important to identify VMFs in intra-articular distal radius fractures. Anatomically designed volar hook plate achieves excellent low-profile stable fixation of this key fragment to allow early mobilisation without fearing loss of reduction and volar carpal subluxation.

Introduction

The technique of volar locked plating using anatomical pre-contoured mini fragment plates have been highly successful and have become the standard of care for treating unstable distal radius fractures (DRF). The contemporary volar locked plates are designed to stabilise both the lateral and the intermediate columns [1] of the distal radius using variable angle locking screws and are meant to be positioned proximal to the watershed line [2]. However, fractures of the distal radius are highly variable in morphology [3] and the unique anatomy of the distal radius makes it challenging to address all fracture components using one implant. The distal radius articular surface has a volar tilt and the relatively flat volar cortex of the radius also curves in a volar direction distally making it difficult to stabilise fracture fragments in the region of the volar rim [4].

The volar lunate facet (VLF) is considered a keystone in distal radius fractures. It articulates with the lunate and also provides attachment for the strong short radiolunate ligament. Failure to address this fragment during surgery can result in volar carpal subluxation and an unstable wrist joint [5]. Typically, volar shear fractures with fragmentation of the volar rim (AO: 2R3B3) and complete articular fractures with a separate VLF fragment (AO: 2R3C3) pose significant risks for late volar carpal subluxation if not properly addressed. The morphology of the VLF fragment is variable. The fragment is often relatively large and triangular in configuration and can be stabilised using the conventional volar locked plates but in some instances, the VLF is comminuted with a separate small and rectangular fragment measuring less than 10 mm in length from the articular rim [6]. These small VLFs, also called as volar marginal fragments (VMF) are distal to the watershed line and are impossible to be stabilised by a conventional volar locked plate.

The problem posed by VMFs in distal radius fracture fixation has been well appreciated in the literature [7]. Authors have proposed different fixation options for these VMFs such as external fixation, rim plates, bent K wires, headless screws, wire loops, suture anchors, pin plates and more recently, hook plate extensions and dedicated

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hook plates [8-12] with successful results. With this background, we describe our experience with a new fragment specific volar distal radius hook plate meant for stabilising the VMF in distal radius fractures.

Methods

18 adult patients who underwent distal radius fracture fixation using the dedicated volar distal radius hook plate at our institution were considered for this retrospective review. The study was approved by our institutional review board and informed consent was obtained from all patients who participated in the review. Adult patients after physeal closure who sustained intra-articular distal radius fractures with presence of a VMF distal to the watershed line in the preoperative CT scan were included. Large, uncomminuted VLF fragments which can be addressed with the standard volar locking plate were excluded. Patients with open injuries, associated neurovascular compromise, presence of carpal injuries and other skeletal injuries in the same limb were also excluded.

Apart from regular PA and lateral radiographs, a CT scan was performed in all patients with intra-articular fractures as part of the preoperative work up. The CT was used to classify fracture patterns, study the articular fracture morphology and decide on the choice of implant.

Surgical technique

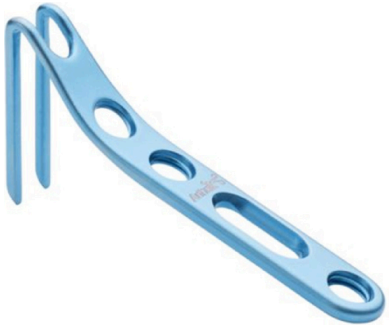

Fig. 1. Image of the volar hook plate used in the study.

Patients were operated in supine position with the arm resting on an arm table. A sterile tourniquet was used. The standard Henry's approach radial to the flexor carpi radialis (FCR) was used in all cases. The volar distal radius was approached in the plane between the radial neurovascular bundle and the FCR tendon followed by elevating a ulnar based pronator quadratus flap. In complete articular fractures, a Z - plasty of the brachioradialis tendon was performed.

To appreciate the VMF, an elaborate exposure of the volar cortex right up to the ulnar articular margin of the distal radius was required. The VMF was reduced and pinned in place provisionally using a K wire. Once reduction of all fracture components was achieved using standard techniques, hook plate fixation was initiated.

The volar distal radius plate (Arthrex, India) has low profile matching the volar curve of the distal radius (Figure 1). It is designed to be positioned on the volar articular rim without much tendon irritation and can be positioned well ulnar on the volar distal radius. These hooks are angulated proximally keeping in mind the articular anatomy of the distal radius. A dedicated jig is available to insert the hooks safely and exactly in the right place.

The jig for the hook plate was positioned in such a way that the two hooks go right up to the volar edge of the articular rim (Figure 2). The tunnel for the hooks were created using two 1.5 mm K wires. The entry of the K wires was marked using a marking pen and the wires were then removed. An appropriate length hook plate was then inserted into the pre drilled tunnels and gently impacted in to place. This secured the VMF and further fixation was completed using 2.4 mm cortical and locking head screws through the plate.

A standard 2 - column volar locking plate cannot be used when a volar hook plate is used. So, to secure the radial column we used the dorsal and radial mini fragment distal radius plates from the I generation Locking Distal Radius System (LDRS, Synthes) and the 2.0 mm T locked plates from the hand system. In one case the volar 2 -column plate was used after it was cut to fit (Figure 3). In cases where articular impaction had to be addressed, autografts from the proximal ulna was used to stabilise the restored articular surface. Intraoperative PA, lateral facet views and dorsal tangential views were performed to assess fracture reduction, articular congruity and presence

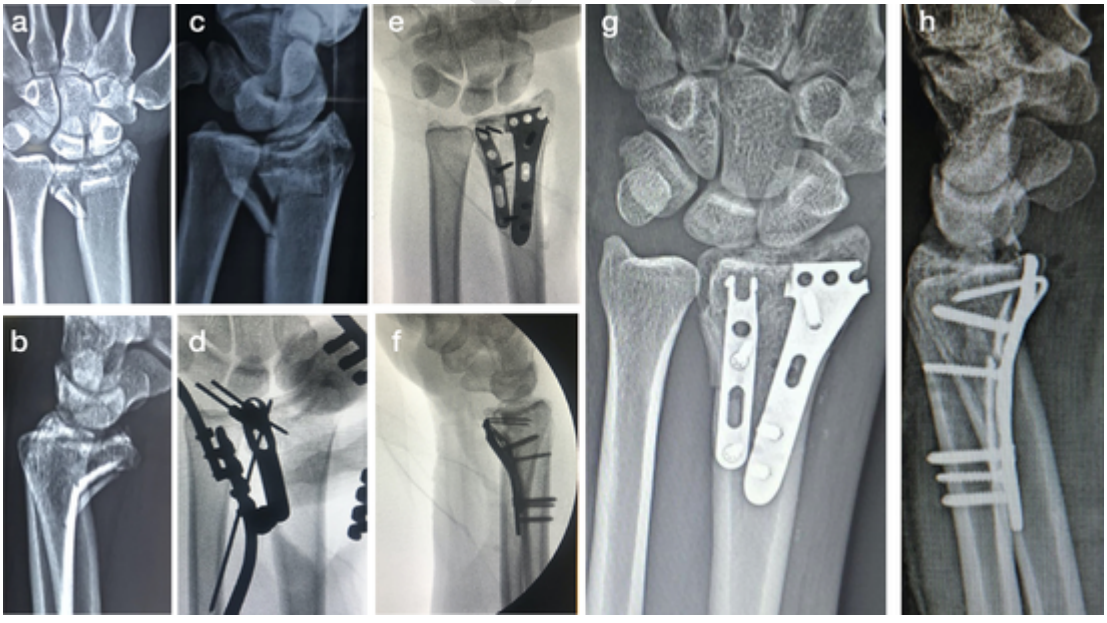

Fig. 2. Pre-surgery radiographs (a - c) show an AO: 2R3C3.3 fracture in a 45 years old male. Intra - operative C arm images show the mounted jig meant for positioning the hook plate (d - f). Anatomical reduction of the VMF and its maintenance can be appreciated through fracture healing in the follow up radiographs (g and h).

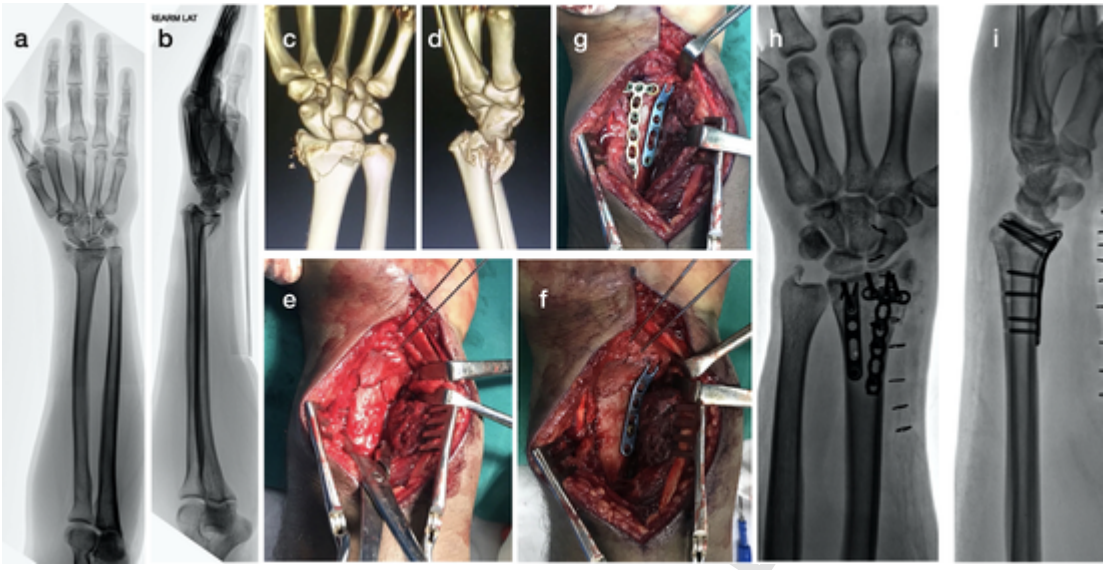

Fig. 3. Pre-operative (a - d) and post-operative x-rays (h and i) show an excellent reduction and stabilization of the VMF in an AO: 2R3C3.2 fracture in a 19 years old female. Intra-operative images (e - g) show the technique of reduction and stabilization of the VMF using the volar hook plate.

of articular or long dorsal screws. The pronator quadratus and the brachioradialis tendon were repaired and the wound was closed.

Post-surgery, patients were placed in a sugar tong splint for a period of 2 weeks. Finger exercises were started from day 1. This was then converted into a detachable wrist splint which could be removed to allow range of motion (ROM) exercises of the wrist and forearm rotations. Patients were reviewed at 6 weekly intervals till fracture healing and then during the final follow up assessment for the purpose of the study. Follow up x-rays were performed during those visits to assess fracture healing, loss of reduction, collapse or subluxation and secondary articular screw penetration. At the final follow up, ROM was assessed clinically and documented. Grip strength was measured using a dynamometer and compared to the opposite side. Functional outcome assessment was performed using surgeon rated Mayo wrist score and the Patient Rated Wrist Evaluation (PRWE) score.

Results

During the study period, we had used the volar hook plate in 23 patients at our institution. 21 patients satisfied the inclusion criteria, out of which 2 patients could not be traced and one patient was not willing to come for follow up. Remaining 18 patients were included in the final analysis. The mean age was 33 ± 10 years. There were 12 B3.3 fractures and 6 C3 fractures. The mean follow -up was 18.7 ± 5.5 months. Complete patient data can be found at Table 1.

All fractures united with no loss of reduction of the VMF (Figure 4). No change in implant position or failure was documented. The mean wrist flexion - extension arc was 105° ± 10.2° The mean forearm prono - supination arc was 145° ± 9.3° The mean grip strength was 19.8 ± 2 kg reaching a mean of 74.6 ± 6% compared to the opposite normal side. The mean Mayo wrist score was 75 ± 5.3%. The mean PRWE score was 15.2 ± 4.3. Please refer to Table 1 for details of functional outcome. One patient underwent removal of im-

Table 1
Patient data.

No	Age/Sex	Fracture (AO type)	Wrist Extension/ Flexion (deg°)	Forearm Pronation/ Supination (deg°)	Grip strength (% of opp side)	Mayo score (%)	PRWE
1	27/M	B3.3	60°/40°	70°/70°	75	80	13
2	32/M	B3.3	60°/45°	75°/75°	76	75	17
3	29/M	C3.2	55°/50°	90°/60°	80	80	14
4	45/M	C3.3	55°/45°	80°/55°	78	80	11
5	51/F	C3.2	65°/45°	70°/75°	76	80	9
6	23/M	B3.3	65°/55°	75°/70°	70	70	16
7	20/F	B3.3	50°/50°	80°/60°	68	75	15
8	40/M	B3.3	55°/50°	80°/65°	73	75	18
9	30/M	B3.3	60°/45°	80°/75°	66	75	14
10	32/M	B3.3	50°/35°	75°/85°	66	60	26
11	38/F	C3.3	45°/40°	65°/80°	68	65	22
12	32/M	B3.3	65°/45°	80°/60°	80	80	10
13	22/M	B3.3	70°/50°	80°/55°	76	75	17
14	19/F	C3.2	55°/35°	75°/55°	84	75	13
15	29/M	B3.3	55°/55°	75°/70°	75	75	12
16	44/M	C3.2	60°/50°	90°/75°	75	75	18
17	50/F	C3.2	65°/50°	75°/80°	88	80	11
18	34/F	B3.3	60°/50°	75°/60°	70	75	17

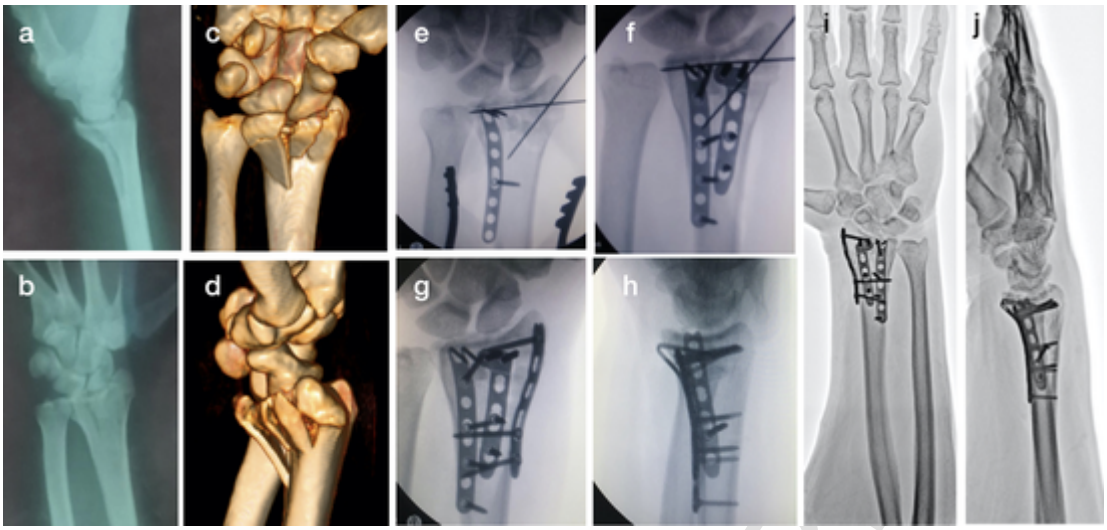

Fig. 4. Pre-operative (a - d), intra-operative (e - h) and post - operative fluoroscopic images (i and j) showing the sequence of reduction of the VMF and the radial column fragments in an AO:2R3B3.3 fracture sustained by a 40 years old male patient.

plants at 9 months due to tendinitis of the flexor pollicis longus (FPL) tendon which settled down after removal of implants. No tendon rupture was encountered. Stability of the radiocarpal and the distal radioulnar joint function was found satisfactory in all patients.

Discussion

The VLF acts as a centroid of force transmission and is considered a keystone to both radiocarpal and distal radio-ulnar articulations. The VLF is the only sector of the distal radius articular surface that effectively resists volar carpal translation [13,14]. So it is imperative that the broken VLF is identified and stabilised using an appropriate implant that can provide rigid fixation and allow early range of motion. Stable fixation of the VLF is the key to healing since small VMF fragments are often avascular [15]. Stable fixation of the VLF however pose several challenges. The fragment is often too small (described as VMF), too distal and ulnar to access through the standard FCR approach and fix it using conventional implants.

All VLFs don't need special implants. So, it is important to identify and differentiate small and distal VMFs from the standard VLFs. As described in our study, a preoperative CT scan is important for proper identification and to understand the morphology of this key fragment. The distal radius study group reported that VMFs are missed in up to 13% of combined type B and C fractures [16]. Failure to rigidly secure this important fragment results in reported failure rates of 4 - 41% [17].

VMFs represent an important osteo-ligamentous structure consisting of the portion of the VLF and attachments of the short radiolunate and the volar distal radioulnar ligament. Since VMFs are small and located distal to the watershed line, achieving stable buttress fixation with the conventional 2 - column volar locking plate is impossible. Several techniques have been described to overcome this problem but they often fail to stabilise this key fragment especially when small and comminuted. Use of additional K wires, wire loops and hook plate extensions are also prone to cause tendon and soft tissue irritations [18]. Suture anchors are difficult to use when the volar cortex is comminuted and also do not stabilise the bony component well [8,11]. The volar rim plate is designed to be positioned distal to the watershed line, can buttress the VMF but getting even small 2.4 mm screws into it can result in fragmentation and loss of fixation [19].

Different types of pin or hook based fixation has been successfully reported for fixation of VMFs in distal radius fractures [20,21]. The volar hook plate used in our series has two parallel hooks of size 1.5 mm. Since drilling is performed with smooth 1.7 mm K wires, the risk of fragmentation is much lower. The hooks which are proximally directed away from the articular surface are also much longer compared to many other systems. This makes fixation extremely secure and stable to allow early ROM at the wrist and the distal radioulnar joint. All patients in our series were allowed ROM as early as 2 weeks and fracture union was achieved without any loss of fracture reduction. Excellent functional outcome without problems of articular incongruity, wrist instability and soft tissue impingement can be expected as shown in our series with the Mayo and PRWE scores.

The hook plate is much lower in profile compared to volar locked plates and can be safely placed distal to the watershed line without fear of soft tissue impingement as shown in our study. It is important to pre-drill adequately and place the hooks flush with the bone to prevent prominence and soft tissue irritation.

We had just one case of FDP tendinitis out of 18 cases (0.5%) which was actually due to impingement at the relatively irregular cut end of a volar 2-column locked plate. We do not recommend this since it's difficult to get rid of the sharp edges which can predispose to tendon irritation as shown in one of our cases.

To visualize and stabilise the VMF with a more radial based approach like the Henry's approach can be difficult. More ulnar based approaches medial to the median nerve providing direct access to the volar-ulnar corner of the distal radius have been described with raising a radial based pronator quadratus flap [22]. Our preference was the Henry type approach radial to the FCR but we extended it distally crossing the wrist crease up to the scaphoid tubercle. This makes access and fixation of the VMF easier without excess retraction and pressure on the median nerve.

The study has its limitations. The sample size was small, a single surgeon series and the study design was retrospective. These factors along with lack of controls mean that the results should be interpreted with caution. Patients were followed up only for a mean period of 18 months which could be still less when evaluating long term problems and we also lost more than 10% of our patients at follow up, which considering the small sample could be significant. No statistical analysis was performed to provide a scientific assessment of our results, though we were able to obtain both surgeon and patient reported scores to assess functional outcome. The concepts about the importance of the volar lunate facet and difficulties in fixation of the volar marginal fragments are relatively new and still

evolving with development of more fragment specific solutions. Hence, we believe this study could add more to the knowledge about VMFs and possible fixation techniques.

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Declaration of Competing Interest

The authors declare that they have no known compe5ng financial interests or personal rela5onships that could have appeared to influence the work reported in this paper.

References

[1] D.A. Rikli, P. Regazzoni Fractures of the distal end of the radius treated by internal fixation and early function. A preliminary report of 20 cases. J Bone Joint Surg Br 1996;78:588–592.
[2] J. Orbay Volar plate fixation of distal radius fractures. Hand Clin 2005;21(3):347–354.
[3] R.J. Medoff Essential radiographic evaluation for distal radius fractures. Hand Clin 2005;21(3):279–288.
[4] J. Andermahr, S. Lozano-Calderon, T. Trafton, et al. The volar extension of the lunate facet of the distal radius: a quantitative anatomic study. J Hand Surg Am 2006;31(6):892–895.
[5] E. Apergis, S. Darmanis, G. Theodoratos, et al. Beware of the ulno- palmar distal radial fragment. J Hand Surg 2002;27:139–145.
[6] J.B. Jupiter, D.L. Fernandez, C.L. Toh, et al. Operative treatment of volar intra-articular fractures of the distal end of the radius. J Bone Joint Surg Am 1996;78:1817–1828.
[7] N.G. Harness, J.B. Jupiter, J.L. Orbay, et al. 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-A:1900–8.
[8] K.R. Chin, J.B. Jupiter Wire-loop fixation of volar displaced osteo- chondral fractures of the distal radius. J Hand Surg Am 1999;24(3):525–533.
[9] D.S. Ruch, C. Yang, B.P. Smith 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.
[10] M.J. Waters, D.E. Ruchelsman, M.R. Belsky, et al. Headless bone screw fixation for combined volar lunate facet distal radius fracture and capitate fracture: case report. J Hand Surg Am 2014;39(8):1489–1493.
[11] A.M. Moore, D.G. Dennison Distal radius fractures and the volar lunate facet fragment: kirschner wire fixation in addition to volar- locked plating. Hand (NY) 2014;9(2):230–236.
[12] E.R. Wiesler, G.D. Chloros, R.M. Lucas, et al. Arthroscopic management of volar lunate facet fractures of the distal radius. Tech Hand Up Extrem Surg 2006;10(3):139–144.
[13] D.A. Rikli, P. Honigmann, R. Babst, et al. Intra-articular pressure measurement in the radioulnocarpal joint using a novel sensor: in vitro and in vivo results. J Hand Surg Am 2007;32(1):67–75.
[14] S. Komura, T. Yokoi, H. Nonomura, et al. Incidence and characteristics of carpal fractures occurring concurrently with distal radius fractures. J Hand Surg Am 2012;37(3):469–476.
[15] R.A. Berger, J.M.F. Landsmeer The palmar radiocarpal ligaments: a study of adult and fetal human wrist joints. J Hand Surg Am 1990;15(6):847–854.
[16] J.S. Souer, D. Ring, J.B. Jupiter AOCID Prospective ORIF Distal Radius Study Group. Comparison of AO Type-B and Type-C volar shearing fractures of the distal part of the radius. J Bone Joint Surg Am 2009;91(11):2605–2611.
[17] J.D. Beck, N.G. Harness, H.T. Spencer Volar plate fixation failure for volar shearing distal radius fractures with small lunate facet fragments. J Hand Surg Am 2014;39(4):670–678.
[18] M.A. O'Shaughnessy, A.Y. Shin, S. Kakar Volar marginal rim fracture fixation with volar fragment-specific hook plate fixation. J Hand Surg Am 2015;40(8):1563–1570.
[19] A.R. Kachooei, M. Tarabochia, J.B. Jupiter Distal Radius Volar Rim Fracture Fixation Using DePuy-Synthes Volar Rim Plate. J Wrist Surg 2016;5(1):2–8. doi:10.1055/s-0035-1570740.
[20] A.J. Bakker, A.Y. Shin Fragment-specific volar hook plate for volar marginal rim fractures. Tech Hand Up Extrem Surg 2014;18(1):56–60.
[21] M.A. O'Shaughnessy, A.Y. Shin, S. Kakar Stabilization of Volar Ulnar Rim Fractures of the Distal Radius: current Techniques and Review of the Literature. J Wrist Surg 2016;5:113–119.
[22] D. Tordjman, R.M. Hinds, O. Ayalon, et al. Volar-Ulnar Approach for Fixation of the Volar Lunate Facet Fragment in Distal Radius Fractures: a Technical Tip. J Hand Surg Am 2016 Dec;41(12):e491–e500. doi:10.1016/j.jhsa.2016.09.007.