International Journal Dental and Medical Sciences Research
Volume 4, Issue 5, Sep-Oct 2022 pp 359-366 www.ijdmsrjournal.com ISSN: 2582-6018

Comparison of functional outcomes in intra-articular distal radius fractures treated with volar plating versus external fixation and adjuvant pin fixation: A prospective randomized study

Rahul A N Gowda[1], Rahul G Puranik[2], Sreekanth B Chavan[3]

1 *Senior resident, Department of orthopedics, VM Medical college and hospital, Solapur, Maharashtra, India.*

2 *Associate professor, Department of orthopedics, BJ Medical college and Sassoon hospital, Pune, Maharashtra, India*

3 *Senior resident, Department of orthopedics, Government Medical college and hospital, Aurangabad, Maharashtra, India*

Submitted: 01-10-2022 Accepted: 10-10-2022

ABSTRACT

Background: Intra-articular distal radius fractures are treated by various methods. Volar plating and external fixation with or without adjuvant pin fixation are the two most commonly used treatment modalities in the management of intra-articular distal radius fractures. The objective of this study was to compare the functional outcomes in intra-articular distal radius fracture patients treated with volar plates and external fixation with adjuvant pin fixation

Material and Methods: Thisprospective study involved totally 50 patients from two groups of patients, each group consists of 25 patients. One group involved patients treated with volar plating and another group involved patients treated with external fixation. One patient from external fixation group was excluded from the study due to loss of follow up.

Results: The follow up rate was 98% at 1 year. Volar plating patients suffered lesser pain and better grip strength at all time points as indicated by difference in subjective assessment wrist scores. Volar plating patients had better range of motion in terms of flexion, extension, supination, pronation, ulnar deviation, radial deviation when compared to external fixation group thought the study period. Volar plating patients had better restoration of radiological parameters in terms of Volar tilt, Ulnar variance, Radial inclinationat 1 year when compared to external fixation group. The differences in wrist scores, range of motion andradiological parameters restoration was statistically significant ($p< 0.05$)

Conclusion: Patients treated with volar plating has better functional outcomes when compared to external fixation. Volar plating results in improved grip strength and range of motion, lesser pain and better restoration of radiological parameters in intra-articular distal radius fracture patients when compared to external fixation and adjuvant pin fixation.

I. INTRODUCTION

Distal radius fractures are one of the most common fractures of the human skeleton [8]. Distal radius fractures usually occur by trivial fall on outstretched hand in elderly [7,9], in younger individuals the mode of injury is usually motor vehicle accidents. Of all the distal radius fractures intra-articular varieties are challenging to treat. Accurate restoration of the articular surface and stable fixation are essential for early rehabilitation and prevention of arthritis. Surgical treatment of the intra-articular distal radius fractures is a common practice. Various methods have been described in literature for treatment of the intra-articular distal radius fractures with good results, the best option remains controversial [5]. Volar platingand External fixation with or without adjuvant pin fixationare the two most widely used methods in the treatment of the intra-articular radius fractures. External fixation being less invasive helps in achieving and maintenance of reduction through ligamentotaxis. Adjuvant pins may be used to hold the articular fragments in place. The external fixation technique provides reasonable results but associated with complications like stiffness of wrist and fingers, loss of reduction, pin tract infections, injury to sensory branch of radial nerve [13]. With the advent of locking plates, volar locking plates are used widely in treating distal radius fractures. Volar locking plates provides angular stable fixation and a reasonably good hold in distal cancellous fragments. Although being invasive, it is possible

International Journal Dental and Medical Sciences Research
Volume 4, Issue 5, Sep-Oct 2022 pp 359-366 www.ijdmsrjournal.com ISSN: 2582-6018

achieve and maintain good articular reduction with locking plates. With the stable fixation achieved by locking plate early post-operative wrist motion can be initiated.

This study involves the comparison of the functional outcomes in intra-articular distal radius fractures treated with Volar plating versus External fixation and adjuvant pin fixation.

II. MATERIALS AND METHODS:

The prospective study group consisted of 50 patients with intra-articular distal radius fractures in tertiary health care center. The study group involved both genders and upon admission were evaluated with history, clinical examination, hematological and radiological investigations. Cases were randomized [into two groups, Group External fixation (Ef) and Group Volar plating (Vp) of 25 cases each using random number tables from computer. One patient from external fixation group lost for follow up and rest 49 patients were followed up for 1 year.

Group Vp patients were operated with volar plating by modified Henry's approach. The skin was incised along the flexor carpi radialis, after incision flexor carpi radialis and flexor hallucis longus tendons were identified and retracted ulnar side. The pronator quadratus was incised in L shaped and was reflected ulnar side to expose the distal radius. The fracture fragments were identified and reduced to position with temporary k-wires. Fracture reduction was confirmed under image intensifier. Fracture stabilized with 2.7 volar locking plates and screws. pronator quadratus was sutured back. Subcutaneous tissue and skin closed in usual fashion. Post-operatively all the patients were given removable volar splint for 15 days. Active finger movements were started from day after surgery. Suture, dressings, splint removed on fifteenth post-operative day. Passive and active wrist movements were encouraged.

Fig 1: Pre-operative and Post-operative antero-posterior and lateral radiographs of intra-articular distal radius fractures treated with volar plating

International Journal Dental and Medical Sciences Research
Volume 4, Issue 5, Sep-Oct 2022 pp 359-366 www.ijdmsrjournal.com ISSN: 2582-6018

Group Ef patients were operated with external fixation and adjuvant pin fixation by single surgeon. Surgeon applied two 3.5mm schanz pins for radius and two 2.5mm schanz pins for second metacarpal with wrist 15^0 ulnar deviation. Distraction rod applied with clamps and joint was distracted. Fracture reduction confirmed under image intensifier. Articular fragments were additionally secured in place with K-wires under fluoroscopic guidance. Over distraction was checked with metacarpo-phalangeal joint movements. Active finger movements began on day after surgery. Active and passive wrist motion was started for all patients once external fixation and K-wires are removed at sixth post-operative week.

Fig2: Pre-operative and Post-operative antero-posterior and lateral radiographs of intra-articular distal radius fractures treated with volar plating

All the patients were followed up for 1 year. The data was collected from each patient at 6^{th} week, 12^{th} week, 6 months, 1year post-operative visits. At each visit patients were evaluated for wrist range of motion in terms of flexion, extension, supination, pronation, radial deviation, ulnar deviation. The range of motion was measuredwith goniometer. Subjective assessment of pain, disability was done using patient rated wrist evaluation score [11] (PRWE) and modified-Mayo wrist score(MMW) at all visits. Radiographic outcomes were assessed at 1 year using standard posteroanterior and lateral radiographs for the measurement of the radial inclination, ulnar variance and volar tilt. At each visit patients were evaluated for complications like tendon injury, complex regional pain syndrome and pin tract infection.

All the data analysis was done using windows statistical software. The statistical analyses were done usingStudent's t test and significance was set at $p<0.05$.

III. RESULTS

The Volar plating and External fixation groups were comparable to each other regarding mean age, sex proportion and dominant side affection. The subjective functional assessment scores and range of motion were assessed and analyzed during every visit. The radiological parameters were assessed at 1year post-operative visit.

International Journal Dental and Medical Sciences Research
Volume 4, Issue 5, Sep-Oct 2022 pp 359-366 www.ijdmsrjournal.com ISSN: 2582-6018

Functional outcomes

In volar plating group the mean PRWE score was 72.08(±8.02) at 6 weeks, 38.44(±6.79) at 12 weeks, 15.16(±4.82) at 3 months and 12.32(±1.84) at 1 year. In external fixation group the mean PRWE score was 88.20(±6.19) at 6 weeks, 57.24(±6.64) at 12 weeks, 25.44(±4.04) at 3 month and 14.84(±2.07) at 1 year.

The mean PRWE scores in volar plating group patients were consistently lower when compared to external fixation group patients throughout the study period (Table 2).Vp group patients toleratedlesser disability and pain.

Table 1: Demographic data of two groups

	Volar plating (Vp) n=25	External fixation (Ef) n=24
Mean age	46.5	49.6
Sex (M/F)	21/4	19/5
Dominant side/non dominant side	17/8	14/10

Table2: Comparison of functional outcome scores between volar plating and external fixation groups

	Volar plating n=25	External fixation (Ef) n=24	P-value
PRWE			
6 weeks	72.08(±8.02)	88.20(±6.19)	0.034
12 weeks	38.44(±6.79)	57.24(±6.64)	0.021
6 months	15.16(±4.82)	25.44(±4.04)	0.047
1year	12.32(±1.84)	14.84(±2.07)	0.0012
MMWS			
6 weeks	44.40(±7.26)	23.80(±5.25)	0.022
12 weeks	64.40(±8.33)	48.00(±6.92)	0.036
6 months	75.80(±10.86)	72.44(±9.47)	0.012
1year	81.60(±10.77)	79.20(±9.75)	0.033

In volar plating group the mean MMW score was 44.40(±7.26) at 6 weeks, 64.40(±8.33) at 12 weeks, 75.80(±10.88) at 3 months and 81.60(±10.77) at 1 year. In external fixation group the mean MMWS score was 23.80(±5.25) at 6 weeks, 48.00(±6.92) at 12 weeks, 72.44(±9.47) at 3 month and 79.20(±9.75) at 1 year. The mean MMW scores in volar plating group patients were consistently higher when compared to external fixation group patients throughout the study period indicating lesser pain and improved grip strength in Vp group.

On applying relevant statistical test (unpaired t-test) the p- values were <0.05 on all occasions making the difference in MMW and PRWE scores between the two groups statistically significant, indicating better functional outcome in Vp group throughout the study period.

Range of motion

In volar plating group the mean flexion was 45.20(±4.18) degrees at 6 weeks, 56.36(±5.13) degrees at 12 weeks, 64.24 (±5.80) degrees at 3 months and 72.84(±6.59) degrees at 1 year. In external fixation group the mean flexion was 31.64(±2.46) degree at 6 weeks, 45.00(±3.31) degrees at 12 weeks, 53.20(±4.80) degree at 3 months and 62.96(±6.87) degrees at 1 year.

In volar plating group the mean extension was 36.04(±4.23) degrees at 6 weeks, 44.40(±3.16) degrees at 12 weeks, 49.28(±3.85) degrees at 3 months and 55.80(±3.87) degrees at 1 year. In external fixation group the mean extension was 26.80(±2.50) degrees at 6 weeks, 39.76(±2.50) degrees at 12 weeks, 43.64(±3.77) degrees at 3 months and 49.20(±6.06) degrees at 1 year.

In volar plating group the mean supination was 50.24(±4.78) degrees at 6 weeks, 69.88(±3.33) degrees at 12 weeks, 83.88(±4.14) degrees at 3 months and 90.16(±5.66) degrees at 1 year. In

International Journal Dental and Medical Sciences Research
Volume 4, Issue 5, Sep-Oct 2022 pp 359-366 www.ijdmsrjournal.com ISSN: 2582-6018

external fixation group the mean supination was 30.72(±2.99) degrees at 6 weeks, 52.52(±6.13) degrees at 12 weeks, 78.16(±4.34) degrees at 3 months and 84.16(±4.02) degrees at 1 year.

In volar plating group the mean pronation was 37.72(±4.84) degrees at 6 weeks, 59.12(±4.00) degrees at 12 weeks, 73.92(±5.29) degrees at 3 months and 81.52(±6.92) degrees at 1 year. In external fixation group the mean pronation was 21.32(±3.53) degrees at 6 weeks, 41.04(±2.97) degrees at 12 weeks, 65.88(±4.92) degrees at 3 months and 76.08(±5.15) degrees at 1 year.

Table 3: Comparison of wrist range of motion between volar plating and external fixation groups

	Volar plating (Vp) n=25	External fixation (Ef) n=24	P-value
Flexion			
6 weeks	45.20(±4.18)	31.64(±2.46)	0.026
12 weeks	56.36(±5.13)	45.00(±3.31)	0.034
6 months	64.24(±5.80)	53.20(±4.80)	0.0011
1year	72.84(±6.59)	53.20(±4.80)	0.038
Extension			
6 weeks	36.04(±4.23)	26.80(±2.50)	0.041
12 weeks	44.40(±3.16)	39.76(±3.46)	0.023
6 months	49.28(±3.85)	43.64(±3.77)	0.031
1year	55.80(±3.87)	49.20(±6.06)	0.022
Supination			
6 weeks	50.24(±4.78)	30.72(±2.99)	0.0014
12 weeks	69.88(±3.33)	52.52(±6.13)	0.024
6 months	83.88(±4.14)	78.16(±4.34)	0.022
1year	90.16(±5.66)	84.16(±4.02)	0.043
Pronation			
6 weeks	37.72(±4.84)	21.32(±3.53)	0.034
12 weeks	59.12(±4.00)	41.04(±2.97)	0.023
6 months	73.92(±5.29)	65.88(±4.92)	0.0015
1year	81.52(±6.92)	76.08(±5.15)	0.045
Radial deviation			
6 weeks	10.68(±1.28)	6.72(±1.74)	0.034
12 weeks	13.72(±1.24)	9.76(±1.45)	0.047
6 months	16.44(±1.82)	14.08(±1.68)	0.002
1year	19.56(±2.34)	17.28(±1.56)	0.007
Ulnar deviation			
6 weeks	16.72(±1.67)	9.20((±1.80)	0.028
12 weeks	19.56(±2.16)	15.88(±2.18)	0.041
6 months	23.04(±2.86)	19.72(±2.28)	0.043
1year	27.20(±3.29)	23.00(±2.88)	0.021

In volar plating group the mean ulnar deviation was 16.72(±1.67) degrees at 6 weeks, 19.56(±2.16) degrees at 12 weeks, 23.04(±2.86) degrees at 3 months and 27.2(±3.29) degrees at 1 year. In external fixation group the mean ulnar deviation was 9.20(±1.80) degrees at 6 weeks, 15.88(±2.18) degrees at 12 weeks, 19.72(±2.28) degrees at 6 months and 23.00(±2.88) degrees at 1 year.

In volar plating group the mean radial deviation was 10.68(±1.28) degrees at 6 weeks, 13.72(±1.24) degrees at 12 weeks, 16.44(±1.82) degrees at 3 months and 19.56(±2.34) degrees at 1 year. In external fixation group the mean radial deviation was 6.72(±1.74) degrees at 6 weeks, 9.76(±1.45) degrees at 12 weeks, 14.08(±1.68) degrees at 3 months and 17.28(±1.56) degrees at 1 year.

International Journal Dental and Medical Sciences Research
Volume 4, Issue 5, Sep-Oct 2022 pp 359-366 www.ijdmsrjournal.com ISSN: 2582-6018

The mean range of flexion, extension, supination, pronation, ulnar deviation, radial deviation movements were consistently higher in Vp group when compared to Ef group patients throughout the study period (Table 3). On applying relevant statistical test (t-test) the p- values were < 0.05 making the difference in all sorts of wrist movements between the two groups statistically significant throughout the study period.

Radiological outcomes

The analysis of radiological parameters (Table 4) like volar tilt, radial inclination and ulnar variance were done at 1 year follow up. The mean volar tilt in Vp group was 4.40(±2.79) degrees and -1.08(±2.11) degrees in Ef group, indicating mean dorsal tilt in Ef group.

The mean radial inclination in the Vp group was 20.04(±2.20) degrees and 14.64(±2.85) degrees in Ef group. The mean ulnar variance in Vp group was -0.42(±0.611) mm and 0.54(±0.51) in Ef group. Radiological outcomeswere better in Vp group when compared to Ef group, which demonstrated positive ulnar variance, mean dorsal tilt and poor restoration of radial inclination.

Table4: Comparison of radiological outcomes between volar plating and external fixation groups

	Volar plating (Vp) n=25	External fixation (Ef) n=24	P-value
Radial inclination	20.04(±2.20)	14.64(±2.85)	0.001
Volar tilt	4.40(±2.79)	-1.08(±2.11)	0.025
Ulnar variance	-0.42(±0.61)	0.54(±0.51)	0.042

Table4: Comparison of complications between volar plating and external fixation groups

Types of complication	Volar plating (Vp) n=25	External fixation (Ef) n=24
Pin tract infection	0	3
Complex regional pain syndrome	0	2
Sensory branch of radial nerve injury	0	2
Carpal tunnel syndrome	1	0
Wound infection	0	0
Tendon rupture	0	0

Complications were assessed (Table4) during every post-operative visit. Higher complication rates were seen in Ef group when compared to Volar plating group. 3 patients from Ef group had pin tract infections which were managed with oral antibiotics. 2 patients from Ef developed complex regional pain syndrome which was managed by physiotherapy. 2 patients from Ef group had superficial radial nerve injury and they recovered spontaneously. One patient from Volar plating group suffered carpal tunnel syndrome post-operatively which resolved spontaneously with splinting and physiotherapy.

IV. DISCUSSION

Various surgical options are available for the treatment of intra-articular distal radius fractures. The primary goals of treatment are adequate restoration of articular surface with minimal or no step-off and early post-operative wrist motion. Articular reduction is achieved directly by opening of fracture site or indirectly by ligamentotaxis. Inadequate restoration of articular

surface, volar tilt, radial inclination leads to poor outcomes with reduced and painful range of motion.

External fixation of the intra-articular distal radius fractures is widely followed because it's cheaper, easier to apply and gives reasonable results [13]. External fixation being minimally-invasive modality of treatment helps in maintenance of fracture reduction through ligamentotaxis. Fracture fragments are aligned and maintained in place by neutralizing soft tissue deforming forces. It is often difficult to achieve and maintain the reduction in communited fractures by external fixation alone and may need augmentation with multiple pins/ k-wires. Various studies like Grewal et al [3] ,Karantana et al[4] and Kumbaraci et al[6] have shown that external fixation is associated with higher rates of complications like loss of reduction, pin tract infection, injury to superficial radial nerve and complex regional pain syndrome. Loss of reduction is well known complication associated with external fixation especially in osteoporotic patients. Over-distraction for prolonged periods leads to weak grip strength, wrist joint stiffness and poor functional outcomes.

In our study we had 3 superficial pin tract infections in Ef group patients, all of them resolved with oral antibiotics. 2 patients in Ef group had radial nerve sensory nerve injury which resolved spontaneously. The injury risk can be minimized by making small skin incision followed by blunt dissection till bone by haemostat [1]. 2 patients in Ef group developed complex regional pain syndrome which was managed by physiotherapy.

Volar locking plates are extensively used in the fixation of the distal radius fractures [12]. Direct visualization and manipulation of fracture fragments enables good articular reduction through modified Henry's approach. Locking plates offers subchondral support,helps in maintaining fracture reduction in osteoporotic fractures. Multiple studies have shown good functional outcomes with the use of volar locking plates in distal radius fractures. The advantages of using volar plates are stable fixation, lesser risk of fractures fragments displacement and early wrist motion can be initiated. Locking plates are found have lesser complications when compared to external fixators. The possible complications [15] with volar plating are wound infection, flexor pollicis longus rupture and carpal tunnel syndrome.In our study one patient from Vp group developed carpal tunnel syndrome which resolved with splinting and physiotherapy. There were no incidences of wound infection or tendon rupture in Vp group.

Recent studies like Navarro et al [10], Williksen et al [16] and Zhou et al [17]have demonstrated good functional outcomes in distal radius fractures by volar plating. Early rehabilitation can be initiated in patients after plating. Stable fixation and lesser risk of loss of reduction post-operatively makes volar plating a favourable option when compared to external fixation. In all these studies Vp group patients demonstrated better range motion and subjective assessment scores, when compared to Ef group. The differences in Ef and Vpgroups regarding range of motion and functional assessment scoreswere significant only during the early post-operative period. However, at 1 year there was no significant difference between the Ef and Vpgroups. In our study, Vp group patients demonstrated higher mean flexion, extension, supination, pronation, ulnar deviation and Radial deviation when compared to Ef group patients.Vp group patients had lesser pain and better grip strength as indicated by better PRWE and MMW scores. The difference in range of motion, subjective assessment scores between Ef and Vp groups was statistically significant both during early and late post-operative periods.

The advantages of the study areit's a prospective randomised study with consideration of only intra-articular distal radius fractures.Volar plating and external fixation groups were comparable to each other regarding demographic characteristics. The probable drawback was the number of fracture fragments and articular surface comminution was not taken into account.

Use of Volar locking plates in the management of intra- articular distal radius fractures has good functional outcomes compared to external fixation during early and late post-operative period. Our study concludes the advantages of using volar locking plates over external fixation in intra-articular distal radius fractures byearly wrist motion,better restoration of radiological parameters and grip strength with lesser complications.

REFERENCES

[1]. Bates, Taylor J. MD; Plucknette, Benjamin F. DO, DPT. Avoiding Complications in Distal Radius Fractures. Journal of Orthopaedic Trauma: September 2021 - Volume 35 - Issue - p s27-s32

[2]. Brocklehurst P, Hoare Z. How to design a randomised controlled trial. British dental journal. 2017 May;222(9):721-6.

[3]. Grewal R, MacDermid JC, King GJ, Faber KJ. Open reduction internal fixation versus percutaneous pinning with external fixation of distal radius fractures: a prospective, randomized clinical trial. The Journal of hand surgery. 2011 Dec 1;36(12):1899-906.

[4]. Karantana, Alexia FRCS(Orth)[1]; Downing, Nicholas D. FRCS(Orth)[2]; Forward, Daren P. FRCS(Orth), DM[2]; Hatton, Mark FRCS(Orth)[2]; Taylor, Andrew M. FRCS(Orth), DM[2]; Scammell, Brigitte E. FRCS(Orth), DM[1]; Moran, Chris G. FRCS(Ed), DM[2]; Davis, Tim R.C. FRCS[2]. Surgical Treatment of Distal Radial Fractures with a Volar Locking Plate Versus Conventional Percutaneous Methods: A Randomized Controlled Trial. The Journal of Bone & Joint Surgery: October 2, 2013 - Volume 95 - Issue 19 - p 1737-1744

[5]. Koval, Kenneth MD; Haidukewych, George J. MD; Service, Benjamin MD; Zirgibel, Brian J. MD. Controversies in the Management of Distal Radius Fractures. Journal of the American Academy of Orthopaedic Surgeons: September 2014 - Volume 22 - Issue 9 - p 566-575

[6]. Kumbaraci, M., Kucuk, L., Karapinar, L. et al. Retrospective comparison of external fixation versus volar locking plate in the treatment of unstable intra-articular distal radius fractures. Eur J OrthopSurgTraumatol **24**, 173–178 (2014).

[7]. Levin LS, Rozell JC, Pulos N. Distal radius fractures in the elderly. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2017 Mar 1;25(3):179-87.

[8]. Liporace FA, Adams MR, Capo JT, Koval KJ. Distal radius fractures. Journal of orthopaedic trauma. 2009 Nov 1;23(10):739-48.

[9]. Luokkala T, Laitinen MK, Hevonkorpi TP, Raittio L, Mattila VM, Launonen AP. Distal radius fractures in the elderly population. EFORT open reviews. 2020 Jun 17;5(6):361-70.

[10]. Mellstrand Navarro, Cecilia MD, PhD; Ahrengart, Leif MD, PhD; Törnqvist, Hans MD, PhD; Ponzer, Sari MD, PhD. Volar Locking Plate or External Fixation with Optional Addition of K-Wires for Dorsally Displaced Distal Radius Fractures: A Randomized Controlled Study. Journal of Orthopaedic Trauma: April 2016 - Volume 30 - Issue 4 - p 217-224

[11]. Paranaíba VF, Santos JB, Raduan J, Moraes VY, Belotti JC, Faloppa F. PRWE application in distal radius fracture: comparison and correlation with established outcomes☆. RevistaBrasileira de Ortopedia. 2017 May; 52:278-83.

[12]. Schneppendahl J, Windolf J, Kaufmann RA. Distal radius fractures: current concepts. The Journal of hand surgery. 2012 Aug 1;37(8):1718-25.

[13]. Shukla R, Jain RK, Sharma NK, Kumar R. External fixation versus volar locking plate for displaced intra-articular distal radius fractures: a prospective randomized comparative study of the functional outcomes. Journal of orthopaedics and traumatology. 2014 Dec;15(4):265-70.

[14]. Souer JS, Lozano-Calderon SA, Ring D. Predictors of wrist function and health status after operative treatment of fractures of the distal radius. The Journal of hand surgery. 2008 Feb 1;33(2):157-e1.

[15]. Thorninger R, Madsen ML, Wæver D, Borris LC, Rölfing JH. Complications of volar locking plating of distal radius fractures in 576 patients with 3.2 years follow-up. Injury. 2017 Jun 1;48(6):1104-9.

[16]. Williksen JH, Frihagen F, Hellund JC, Kvernmo HD, Husby T. Volar locking plates versus external fixation and adjuvant pin fixation in unstable distal radius fractures: a randomized, controlled study. The Journal of hand surgery. 2013 Aug 1;38(8):1469-76.

[17]. Zhou, Y., Zhu, Y., Zhang, X. et al. Comparison of radiographic and functional results of die-punch fracture of distal radius between volar locking plating (VLP) and external fixation (EF). J OrthopSurg Res **14**, 373 (2019)