

REVIEW ARTICLE

A Review on Outcomes of Distal Radius Fracture Treated With Different Modes of Treatment and Rehabilitation

Asad Aziz, Aqeel Ahmed Memon, Idress Shah, Imtiaz Hashmi, Sohial Rafi

Department of Orthopedics and Spine Surgery, Dr. Ziauddin University Hospital, Clifton, Karachi, Pakistan.

ABSTRACT

Fractures around wrist joint are common complication happening after fall on an outstretched hand. It is more common in female, and mostly in age above 55 years. Different methods of treatment has been established such as surgical and conservative management, each mode of treatment has its own complication such as, pain, stiffness, swelling, deformity, infection. Non operative treatment include splinting or casting with or without reduction, operative treatment includes percutaneous k-wiring, external fixator for complex fracture or fracture with open wound, open fixation with volar or dorsal plate. Still there is controversy that what method is better in getting the good functional outcome, minimizing the duration of cast immobilization, early fixation, and early start of rehabilitation. All of them play part in better functional outcome. In the past manipulation and fixation without opening the fracture site has been the choice of treatment, comparatively in recent advances fixation with plate through anterior approach is a preferred option because it has less complication rate, plays better role in early range of movement. The information was retrieved from reliable search engines e.g. PubMed, Medline, Google scholar and others, through original research papers and reviews from 2003 to 2019. Purpose of this study is to know which method of management has better outcome and its role in early rehabilitation.

Keywords: Fracture; Radius; Rehabilitation; Casting; External Fixator.

Corresponding Author:

Dr. Asad Aziz

Department of Orthopedics and Spine Surgery

Dr. Ziauddin University Hospital,

Clifton, Karachi, Pakistan.

Email: asadaziz31@gmail.com

doi.org/10.36283/PJMD9-2/015

INTRODUCTION

Incidence of distal radius fracture is high among older age group, more predominantly in females. Women aged 60 and older age group are more prone to have distal radius fracture on minor fall due to osteoporosis in this age group^{1,2}. Due to accelerated bone breakdown in old age population osteopenia and osteoporosis is likely to occur. In women after cessation of menstruation bone, related problems are likely to occur due to decrease in estrogen³. Fracture of distal radius accounts for upto 18 % of upper extremity fracture⁴. Typically, mechanism of injury is fall onto an outstretched hand. Patient who have intact neuromuscular system and less tendency to fall due to dementia or other medical conditions are more prone to fall on outstretched due to their reflexive ability as oppose to falling on side⁵.

There are different options of management in distal

radius fracture, such as; close reduction and plaster, al stabilization, fixation with volar or dorsal plate which can be treated conservatively. Treatment option may varies on certain criteria; patient age, fracture fragments, life style, condition of soft tissue, alignment of fracture^{6,7}. Close reduction and casting can be performed in emergency setup with less cost and without admission to hospital; however it is related to less anatomical reconstruction. Reconstruction is necessary part in displaced fracture, for anatomic restoration of bone fragments. Surgical management is related to more exposure to radiation, financial expense.

Open reduction internal fixation has better outcome in young population as compared to old age in response of better clinical outcome, old age patient who are treated with manipulation and casting have good functional outcome even if treated with some mal-alignment, functional outcomes in elderly patient does not correlate with

mal-alignment⁷. Treatment of distal radius fracture is still controversial as similar outcome is observed in several studies over period of 1 year no matter the choice of treatment, but short follow up has shown better outcome in surgery with volar plating⁸⁻¹⁰. Purpose of this review was to identify which mode of treatment has better functional outcome.

DISCUSSION

Distal radius can happen after a trauma to wrist or forearm, usually patients present with fall on outstretched hand (FOOSH). In elderly patients, it often results from minor fall due to weaker bones¹¹. It has been observed that both non-surgical and surgical methods have been explained in past for treating distal radius fracture¹². Purpose of all the studies was to restore anatomical reduction, have better range of movement and maximum recovery of pre-surgical status¹³.

Clinical Assessment

Clinical history plays important role in deciding management of fracture, like how patient has fell, presenting complain, time of injury, mode of injury, information such as inability to perform movement and deformity and involve some basic questions such as hand dominance, hobbies. It should also be asked if the patient had any previous injury to same site, any medical condition affecting joints such as osteoarthritis and rheumatoid arthritis, which will limit pre-injury mobility status of wrist joint. Inquiry about the daily demands of patient, such as if the patient is required to hold walking aids plays important role in deciding treatment

Radiological Assessment

Radiographic views of wrist include (antero-posterior and lateral views) are sufficient for deciding type of fracture, for complex fracture which are difficult to explain on x-rays we should perform CT scan to know exact configuration of fracture which will help in making surgical plan (Figure 1). Important parameters which are seen on x-rays are radial height (11 to 12 mm), radial inclination (23 degree), displacement of fracture (volar or dorsal), ulnar variance, comminution, joint involvement¹⁴. In conservative treatment of distal radius after casting x-rays should be attained to

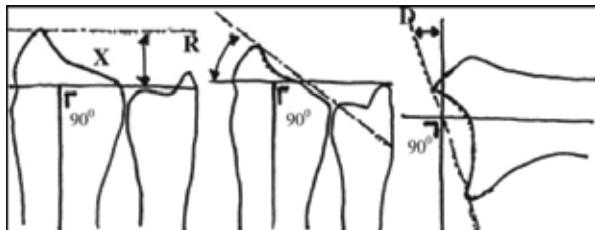


Figure 1: Radial height x=11mm, radial inclination R= 22 degree, angulation D= 10 degree^{14,15}.

know if previous mentioned parameters are achieved.

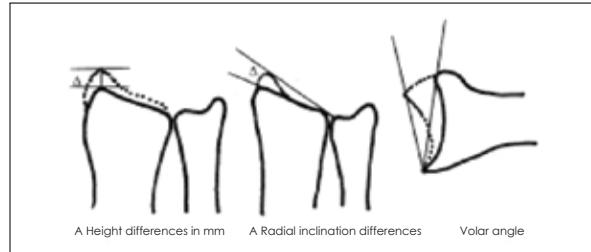


Figure 2: Normal side x-rays are taken as templates to measure the correction required in distal radius fracture^{14,15}.

X-rays of normal side are taken as template to access the normal height, angulation and displacement, template is made on transparent sheet (Figure 2). In this way, it will be easy to make surgical plan that how much correction is required¹⁵.

Classification System

Distal radius fracture has been classified into several classification systems, but it is not necessary to remember all classification. Classification is important in respective of that it is easily communicated between doctors that what type of fracture it is even without seeing the radiographs.

Distal radius fractures are commonly named as Colles, Smith, Volar Barton or Dorsal Barton, which is used to identify type of fracture. However, this does not tell amount of communication of fracture, involvement of radioulnar or radiocarpal joint, it also does not tell about involvement of ulnar styloid. For that, several Classification Systems have been explained during the last quarter of 20th century¹⁶. Commonly used classification for distal radius fracture are namely as Frykman, Fernandez, AO/OTA, Older System, and Melone (Figure 3, 4).



Figure 3: It does not matter what classification system you are using, but what is must that it should explain the extent and position of fracture fragment (displacement, rotation, and angulation, shortening) (taken from handbook of fracture 5th edition 2015).

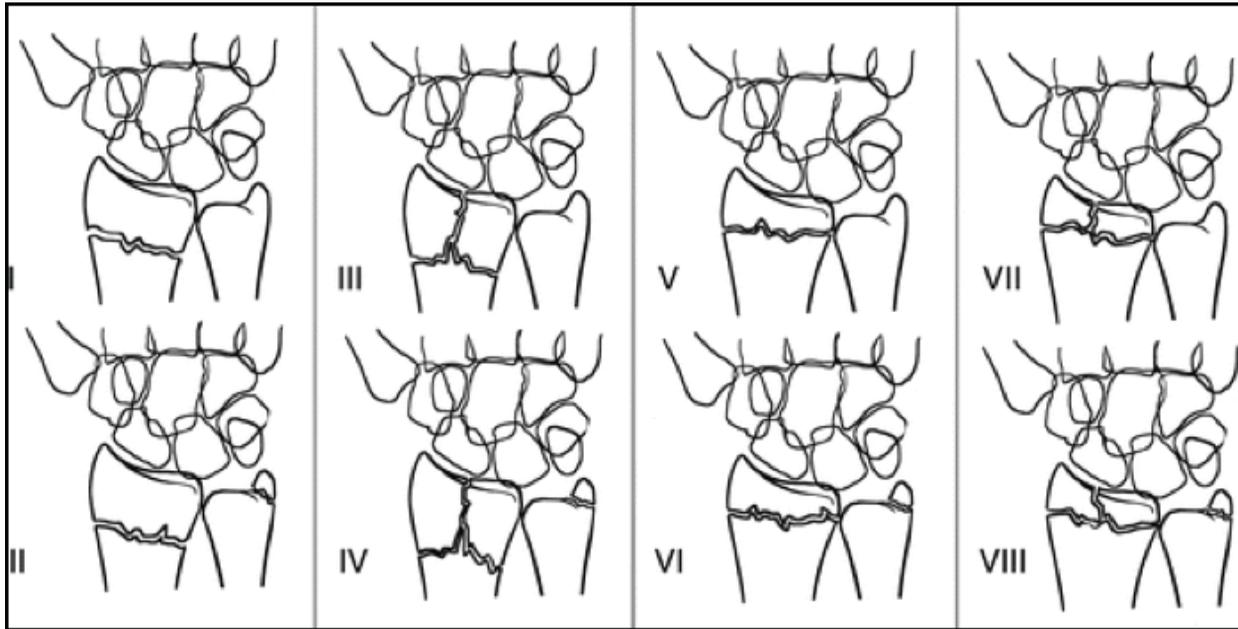


Figure 4: Frykman classification (taken from Rockwood and Green's Fracture in Adults 7th edition, 2010).

Frykman explained the involvement of radiocarpal and radioulnar joint, and also involvement of ulnar

styloid explained in Table 1.

Table 1: explanation of Frykman classification.

<p>Type 1</p> <p>Extra-articular distal radius fracture</p>	<p>Type 3</p> <p>Intra-articular fracture involving radio-carpal joint</p>	<p>Type 5</p> <p>Intra-articular fracture involving distal radio-ulnar joint</p>	<p>Type 7</p> <p>Intra-articular fracture involving radio-ulnar and radio-carpal joint</p>
<p>Type 2</p> <p>Extra-articular distal radius fracture + ulnar styloid fracture</p>	<p>Type 4</p> <p>Intra-articular fracture involving radio-carpal joint + ulnar styloid fracture</p>	<p>Type 6</p> <p>Intra-articular fracture involving distal radio-ulnar joint + ulnar styloid fracture</p>	<p>Type 8</p> <p>Intra-articular fracture involving radio-ulnar and radio-carpal joint + ulnar styloid fracture</p>

Modes of Treatment and Rehabilitation

American academy of orthopedic surgeons (AAOS) clinical practice guidelines on distal radius fracture, team was unable to decide which mode of treatment is better in elderly population¹⁷. Kodama, made a scoring to help in deciding treatment option for distal radius fracture. For patients aged more than 50, factors include fracture configuration, hand dominance, radiographic parameters, and occupation. In multiple studies's Authors found close association of clinical outcome and comminution of the posterior cortex and anterior cortex after reduction, volar tilt

before and after close reduction and ulnar variance after close reduction¹⁸.

1. Non-Surgical

In one study Shrestha et al.¹⁹, included sixty patient in study with different age groups who presented with fracture of distal radius outside joint and non-comminuted. Patients were divided into two equal groups, cast or pins were removed at around 6 to 8 weeks. Functional and radiological outcome was better in pin group, cast group has also shown collapse of radial height (<0.001). There was another study by Brogren et al.²⁰, they found that

risk of union at wrong position in the form of radial deviation and dorsal displacement or angulation is higher in osteoporosis group as compared to patients with normal healthy individual.

Christersson et al.²¹ did a randomized study in treating reduced distal radius fracture with plaster cast for 10 days versus 1 month. Divided into two groups active (cast removed after 10 days) and control group (cast removed after 1 month). Only three cases out of 54 cases in active group treatment were unsuccessful, there was no failure in control group. Two of these have shown radiographic changes such as more displaced fracture after cast is removed at 10th day, had to be changed to surgery with volar locking plate.

Egol et al.²² in their study has compared non-operative versus percutaneous pinning and open reduction internal fixation. Radiological outcomes were better in patients with operative treatment as compared to non-operative, operated group has better grip strength, but

non-operated group has better supination. DASH score was relatively equal in both groups showing equal functional outcome. In one study²³, researchers did a randomized control trial on 60 patients; patients were aged 24 years to 73. Two methods were adopted in his trial casting and percutaneous pinning and casting for distal radius fracture. SF-36 score was used to see outcomes, radiographic outcome was better in percutaneous pinning and casting, but there was no difference in functional outcome and pain.

2. Surgical

Nowadays surgery has more benefit over close reduction and percutaneous wiring, in several studies they have shown that there is prominent difference in patients treated with surgery, they have shown better movement, better grip strength, less pain possibly because of their superior biomechanical properties which is supporting the physiological loads put on wrist joint^{24,25}.

Table 2: Outcome of the studies included in this review article.

First author (Year)	Intervention	DASH score	VAS Pain score	Range of wrist flexion	Range of wrist extension	Radial deviation	Ulnar deviation	Grip strength
Shrestha 2017	Cast	Fair	NA	m- 42.73	m- 39.87	m- 11.87	m- 37.00	m-
	K-wiring	Good		m- 49.20	m- 53.20	m- 14.47	m- 47.13	78.67 m- 90.67
Egaol 2010	Non-operative	Fair	1.5	m- 51.8	m- 54.6	m- 22.9	m- 30.3	m- 27.9
	Operative	Good	1.2	m- 47.8	m- 54.8	m- 18.7	m- 29.9	m- 39.0
Venkatesh 2016	Cast	Good	2	m- 63	m- 61	m- 16	m- 22	NA
	K-wiring	Good	1.7	m- 64-5	m- 62	m- 17	m- 23	
Navarro 2016	External fixation	Fair	NA	m- 68	m- 57	m- 23	m- 28	m- 59
	Volar locking plate	Good		m- 76	m- 58	m- 23	m- 28	m- 63
Crosby 2017	Nonspanning external fixation	Fair	NA	m- 66.7	m- 62.4	m- 30.3	m- 46.1	m- 51.5
	Volar locking plate	Good		m- 59	m- 62	34	m- 21	m- 60

Wei 2009	External fixation	Fair	1.8	m- 91	m- 81	m- 100	m- 91	m- 94
	Radial column plate	Fair	2..3	m-83	m- 82	m- 95	m- 95	m- 73
	Volar plate	Good	1.8	m-89	m- 92	m- 95	m- 100	m-94
Drobetz 2016	Cast	Fair		m- 49	m- 48	NA	NA	m- 42
	Volar locking plate	Good		m- 60	m- 65			m- 64

M – mean value in degree, NA – not applicable

3. Volar Locking Plate

In the younger age group surgery is the main stay to have early range of movement to make the person active as soon as possible, patients with dominant hand fracture are also treated with internal fixation. Intra-articular fracture is also treated with volar plate as articular step of is not acceptable in any joint.

Volar locking plate was introduced in 1990s; it has shown good clinical outcome and radiological results. With volar locking plate, one can achieve earlier range of movement, which helps in earlier return of function²⁶. In one study Navarro et al.²⁷, did a randomized controlled trial on 134 patients comparing external fixation with the anterior locking plate, there was not much difference in DASH score of patients at 2 weeks, 6 weeks and 3 month follow up in both the group. Grip strength and movement was better in anterior locking plate group at 3 months follow, but there was not significant difference at 1-year follow up. Patient with volar locking plate has shown better radial deviation at 1-year follow up. Surgical time was more in volar locking plate group with an average of 70 minutes then external fixation, which is 42 minutes on average.

a) Percutaneous Pinning and External Fixation

It is among the cheaper option in treating and maintaining reduction of operative distal radius fracture. Challani et al.²⁸, compared casting and k wiring with external fixation and k wiring. Patients did not shown significant difference in pain, strength of gripping objects and range of motion.

Agrawal et al.²⁹, in their study they included 30 patients with 15 patients on each group. Period of immobilization was ranged between 5 to 6 weeks. In the conservative group, 10 patients had excellent outcome, 2 had fair results and 3 had poor outcome. In patients with external fixation, 13 patients had excellent outcome, 1 had fair and 1 had poor outcome. At the conclusion, they reported that both the modalities has similar outcome in long-term follow up.

b) Internal Fixation

Fixation with plate is always a better option, primarily in young individual. In North America operative treatment with volar locked plate is seen as a growing trend in patient with displaced distal radius fracture^{30,31}. Leung et al. has differentiated external fixation with plating. He did a randomized study on 144 patients with distal radius fracture involving joint, with an average age of 42 years. At 2 years, follow up external fixation group has shown 39% excellent, 52% good outcome and patients with internal fixation has shown 67% excellent and 30% good outcome. Gartland and Werley scoring system were performed to assess outcome. A significant difference was noted (p=0.04)³².

Kumar studied 71 patients and compared the incidence of complications in low profile dorsal plate and volar plate. The range of back pain was 89% better Good maintenance and 11% fair maintenance. In contrast, the volar plating group was 96% better good maintenance and only 4% fair maintenance. Wrist evaluation scores related to patients were comparable between two groups³³. Wei did a controlled trial on 46 patients, compared with external fixation and or internal fixation with anterior plate, average age recorded was 58 years. Patients who were treated with anterior plate had better Disabilities of the Arm; Shoulder and Hand (DASH) score compared to patients treated with external stabilization at 3 months follow up and subsequently at 1 year follow up. Range of movement at 6 weeks follow up had shown no significant difference between two groups³⁴.

c) Rehabilitation Outcomes

It is still debatable that what post-operative rehabilitation regimen is required in patients with distal radius fracture. Patient with internal fixation with plate can achieve early range of movement as compared to patient treated with casting. In one study³⁵, authors described that pain is the important predictor causing disability in-patient who underwent fixation with volar locking plate, in their study

patient did not get any benefit from formal physical therapy, so they suggested more active and autonomous therapy.

Rehabilitation of distal radius fracture is mainly focused on pain management, early movement, better grip strength and function. If splint or complete plaster is applied, the rehabilitation is mainly focused on small joints of hand and elbow range of movement while the wrist is immobilized. So elbow joint and small joints of hand did not get stiff during the period of immobilization in order to reduce edema³⁶.

Valdes et al.³⁷ conducted a study in which he showed the mean follow up required to re-start movement in two groups. An early range of movement (ROM) group had internal fixation and late range of movement group treated with manipulation and plaster in patients with distal radius fracture. Therapy visits required in early ROM group with an average of 6.5 days as compared to late ROM group in which 17 therapy days were required on an average.

In one study Drobotz et al.³⁸ described that 161 patients who had fracture of distal radius underwent fixation with volar plating were kept immobilized for initial 1 week after surgery, then followed with physiotherapy once weekly for 6 weeks with removable splint. At 6 months, follow up better flexion and extension movement was recorded at wrist joint; there was also a good supination and pronation movement. At 1 year, follow up grip strength was also better. Each study in this article has mainly focused on early range of movement, no matter what is the mode of treatment. Range of movement is one of the most reported outcomes seen in these studies. This literature suggests that early range of movement at wrist and digits will play role in determining the patient satisfaction.

CONCLUSION

Management of distal radius fracture and rehabilitation has remained a topic with controversy. Nowadays fixation with volar plating has more weightage than percutaneous pinning and casting for distal radius fracture as we can achieve early movement in patients with volar plating, and better grip strength. Early involvement in therapy program can be beneficial to some patients and will ultimately reduce number of therapy visits to regain function. So we come to the conclusion that early fixation with volar locking plate has to be the choice of treatment for the patients with distal radius fracture to gain early range of movement and better functional outcome. Further workup required in this topic.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Dr. Ziauddin University Hospital, Clifton, Karachi.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION

AAM and IS has helped in writing the article. IH and SR has corrected the mistakes and made it possible for AA to write this article for the journal.

REFERENCES

1. Azad A, Kang HP, Alluri RK, Vakhshori V, Kay HF, Ghiassi A. Epidemiological and treatment trends of distal radius fractures across multiple age groups. *J Wrist Surg.* 2019.
2. Jordan RW, Naeem R, Jadoon S, Parsons H, Shyamalan G. cast immobilisation versus wire fixation in the management of middle-aged and elderly patients with distal radius fractures. *J Hand Surg.* 2016;21(01):18-23.
3. Mulders MA, Rikli D, Goslings JC, Schep NW. Classification and treatment of distal radius fractures: a survey among orthopaedic trauma surgeons and residents. *Eur J Trauma Emerg Surg.* 2017;43(2):239-48.
4. Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. *Hand Clinics.* 2012;28(2):113-25.
5. DeGoede KM, Ashton-Miller JA, Schultz AB. Fall-related upper body injuries in the older adult: a review of the biomechanical issues. *J Biomech.* 2003;36(7):1043-53.
6. Singh R, Goyal R. Functional and radiological outcome of unstable distal radius fracture treated by conservative or volar buttress plate. *Int J Orthop.* 2018;4(2):80-3.
7. Wang WL, Ilyas AM. Dorsal bridge plating versus external fixation for distal radius fractures. *J Wrist Surg.* 2019.
8. Wilcke MK, Abbaszadegan H, Adolphson PY. Wrist function recovers more rapidly after volar locked plating than after external fixation but the outcomes are similar after 1 year: A randomized study of 63 patients with a dorsally displaced fracture of the distal radius. *Actaorthopaedica.* 2011;82(1):76-81.
9. Li-hai Z, Ya-nan W, Zhi M, Li-cheng Z, Hong-da L, Huan Y, et al. Volar locking plate versus external fixation for the treatment of unstable distal radial fractures: a meta-analysis of randomized controlled trials. *J Surg Res.* 2015;193(1):324-33.
10. Sadik DG, Abdali Z. Open reduction and internal fixation compared to closed reduction and external fixation in distal radial fractures: A randomized study of 40 patients. *Kerbala J Med.* 2014;7(1):1842-9.
11. Meena S, Sharma P, Sambharia AK, Dawar A. Fractures of distal radius: an overview. *J Family Med*

- Prim Care. 2014;3(4):325.
12. Yetkin H, Altay T, Ozan F, Kayalı C, Koyuncu S. Comparison of open reduction volar locking plate fixation and closed reduction percutaneous K-wire fixation in the treatment of AO type C1 distal radius fractures. *Int J Clin Exp Med*. 2017;10(1):1139-44.
 13. Oshige T, Sakai A, Zenke Y, Moritani S, Nakamura T. A comparative study of clinical and radiological outcomes of dorsally angulated, unstable distal radius fractures in elderly patients: intrafocal pinning versus volar locking plating. *J Hand Surg*. 2007;32(9):1385-92.
 14. Pratap D, Deane AK, Peshin C. Radiological evaluation of distal radio-ulnar joint congruency in distal radius fractures. *Int J Orthop*. 2018;4(1):787-91.
 15. Van Eerten PV, Lindeboom R, Oosterkamp AE, Goslings JC. An X-ray template assessment for distal radial fractures. *Arch Orthop Trauma Surg*. 2008;128(2):217-21.
 16. Wolfe SW, Pederson WC, Hotchkiss RN, Kozin SH, Cohen MS. *Green's operative hand surgery: the pediatric hand E-book*. Elsevier Health Sciences; 2010.
 17. Lichtman DM, Bindra RR, Boyer MI, Putnam MD, Ring D, Slutsky DJ, et al. Treatment of distal radius fractures. *J Am Acad Orthop Surg*. 2010;18(3):180-9.
 18. Kodama N, Takemura Y, Ueba H, Imai S, Matsuue Y. Acceptable parameters for alignment of distal radius fracture with conservative treatment in elderly patients. *J Orthop Sci*. 2014;19(2):292-7.
 19. Shrestha B, Pandey A, Singh GP, Shrestha KM, Shrestha R. Closed reduction and cast versus percutaneous pinning in distal radius fracture. *J Univ Coll Med Sci*. 2017;5(1):1-7.
 20. Brogren E, Petranek M, Atroshi I. Cast-treated distal radius fractures: a prospective cohort study of radiological outcomes and their association with impaired calcaneal bone mineral density. *Arch Orthop Trauma Surg*. 2015;135(7):927-33.
 21. Christersson A, Larsson S, Östlund B, Sandén B. Radiographic results after plaster cast fixation for 10 days versus 1 month in reduced distal radius fractures: a prospective randomised study. *J Orthop Surg Res*. 2016;11(1):145.
 22. Egol KA, Walsh M, Romo-Cardoso S, Dorsky S, Paksima N. Distal radial fractures in the elderly: operative compared with nonoperative treatment. *J Bone Joint Surg Am*. 2010;92(9):1851-7.
 23. Venkatesh RB, Maranna GK, Narayanappa RK. A comparative study between closed reduction and cast application versus percutaneous k-wire fixation for extra-articular fracture distal end of radius. *JCDR*. 2016;10(2):RC05.
 24. Crosby NE, Cooney T, Seeds W, Lubahn JD. Treating unstable distal radius fractures with a nonspanning external fixation device: comparison with volar locking plates in historical control group. *Am J Orthop*. 2017;46(5):E344-52.
 25. Lian Z, Yang J, Zhang T, Chuang MA, Liu Q, Yang G. Bridging external fixation combined with Kirschner-wire fixation versus volar locked plate fixation for unstable fractures of the distal radius. *Chin J Tissue Engineer Res*. 2016;20(44):6590-8.
 26. Sirniö K, Leppilahti J, Ohtonen P, Flinkkilä T. Early palmar plate fixation of distal radius fractures may benefit patients aged 50 years or older: a randomized trial comparing 2 different treatment protocols. *Acta orthopaedica*. 2019;90(2):123-8.
 27. Navarro CM, Ahrengart L, Törnqvist H, Ponzer S. Volar locking plate or external fixation with optional addition of K-wires for dorsally displaced distal radius fractures: a randomized controlled study. *J Orthop Trauma*. 2016;30(4):217-24.
 28. Challani A, Agrawal A, Kadam R, Jain V, Shah A, Pandey S. Assessment of radiological evidence of collapse of distal end radius fracture after treating with cast, percutaneous k-wire fixation and external fixator. *Int J Res Orthop*. 2018;4(3):367.
 29. Agrawal V, Rohit K. Distal radius fractures: A comparative study between conservative management and external fixation. *JEMDS*. 2017;6:1093-8.
 30. Huetteman HE, Shauver MJ, Malay S, Chung TT, Chung KC. Variation in the treatment of distal radius fractures in the United States: 2010 to 2015. *Plastic Reconstr Surg*. 2019;143(1):159-67.
 31. Walenkamp MM, Mulders MA, Goslings JC, Westert GP, Schep NW. Analysis of variation in the surgical treatment of patients with distal radial fractures in the Netherlands. *J Hand*. 2017;42(1):39-44.
 32. Leung F, Tu YK, Chew WY, Chow SP. Comparison of external and percutaneous pin fixation with plate fixation for intra-articular distal radial fractures. A randomized study. *J Bone Joint Surg Am*. 2008;90(1):16-22.
 33. Kumar S, Khan AN, Sonanis SV. Radiographic and functional evaluation of low profile dorsal versus volar plating for distal radius fractures. *J Orthop*. 2016;13(4):376-82.
 34. Wei DH, Raizman NM, Bottino CJ, Jobin CM, Strauch RJ, Rosenwasser MP. Unstable distal radial fractures treated with external fixation, a radial column plate, or a volar plate: a prospective randomized trial. *J Bone Joint Surg Am*. 2009;91(7):1568-77.
 35. Lee SJ, Park JW, Kang BJ, Lee JI. Clinical and radiologic factors affecting functional outcomes after volar locking plate fixation of dorsal angulated distal radius fractures. *J Orthop Sci*. 2016;21(5):619-24.
 36. Dilek B, Ayhan C, Yagci G, Yakut Y. Effectiveness of the graded motor imagery to improve hand function in patients with distal radius fracture: A randomized controlled trial. *J Hand Ther*. 2018;31(1):2-9.
 37. Valdes K. A retrospective pilot study comparing the number of therapy visits required to regain functional wrist and forearm range of motion following volar plating of a distal radius fracture. *J Hand Ther*. 2009;22(4):312-9.
 38. Drobetz H, Koval L, Weninger P, Luscombe R, Jeffries P, Ehrendorfer S, et al. Volar locking distal radius plates show better short-term results than other treatment options: A prospective randomised controlled trial. *World J Orthop*. 2016;7(10):687.