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"The New Concept Of Polyaxial Locked Plate Fixation In Intra-Articular Fractures Of The Distal Radius"

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ABSTRACT:

Background: 8–15% of all broken bones were distal radius fractures. Many of these fractures were managed with close reduction and cast immobilization. Open reduction and internal fixation achieved by using the volar approach (modified Henry approach). Polyaxial locking plates was the standard treatment for distal radius fractures.

The Aim was to evaluate the radiological and the functional outcomes of management of intra-articular distal radius fractures using Polyaxial Volar Locked Plate and assess the complications.

Methods: in the period between October 2021 and May 2022, a prospective study was carried out consisting of 20 cases (16 male & 4 female) met the requirements for inclusion criteria and finished the follow-up period of six months.

Results: At six months, MAYO and Quick-DASH scores were statistically significant. The functional results according to comparison of 3rd month & 6th month follow-up results was statistically significant for flexion, extension, radial & ulnar deviation. The final clinical outcome was related smoking.

Conclusion: Polyaxial locked plate fixation for distal radius fractures restores hand, wrist, and forearm function with high range of motion and stability. In unstable bony fragments like AO 23– C1 & C2 and C3 distal radial fractures, Polyaxial plate fixation yielded the best functional results. The rate of complications and reoperation was minimum.

Type Of Study: Descriptive prospective pre-post quasi experimental study.

Key Words: Polyaxial, Volar Locking Plate, Radial Fractures, Modified Henry approach

Introduction

One-sixth of emergency room fractures was distal radius fractures [1]. The best method of treating unstable (intra and extra articular) fractures was debatable [2]. External fixation [3, 4], pinning [2, 3], and dorsal plating were common fixation methods in the past. External fixation devices were uncomfortable, require maintenance for 6 to 8 weeks, and some fractures redisplaced after device removal [4, 5]. For displaced intraarticular fractures, percutaneous K-wire pinning was less stable [6]. Distal screws must be placed subchondrally to avoid loss of correction and to assist positive functional outcomes [7].

Volar locking plates may provide sufficient stability for fractures that have been displaced dorsally, according to recent biomechanical studies [8]. The application of a volar implant aims to achieve true radial column support as well as accurate and safe subchondral screw placement [9]. The volar plate needs to be near the watershed line to stabilise the articular fragments after comminuted intra-articular radius fractures. According to several authors, K-wire with dorsal plating was used to treat AO type C3 comminuted fractures. Variable angles plates help screws engage fracture fragments without intraarticular penetration [10].

Biomechanics and Mechanism of Injury

The wrist joint articulations allow palmar flexion and dorsiflexion in the sagittal plane, radial and ulnar deviation in the frontal plane. Normal wrist ROM is 65° to 80° of flexion and 55° to 75° of extension. With a slight palmar tilt of the wrist joint, flexion exceeds extension by an average of 10° [11]. The movement in both planes is to allow circumduction, but its natural motion is a composite of these [12]. Ulnar deviation ranges from 0 to 35 to 40 degrees. Radial deviation ranges from 0 degrees to 15–20 degrees (Figure 1) [13]. It appears that 45° wrist motion (10° flexion and 35° extension) is sufficient for most activities. In the dominant and the non-dominant wrist 10° of extension is probably the most versatile position of wrist fusion [14].

Biomechanics of the distal radio-ulnar joint

The radius carries 80 percent of forearm's axial load through its articulation with lateral carpus, while ulna carries 20 percent via the triangular fibrocartilage complex (TFCC) with medial carpus [15]. The ulnar head moves dorsally in the sigmoid notch during pronation. It moves anteriorly during supination. The TFCC is primary stabilizer of Distal Radial Ulnar Joint (DRUJ). The forearm's interosseous membrane, pronator quadratus muscle, and extensor and flexor carpi ulnaris tendons are additional stabilizers for motion and stability. Deformity after a fracture affects wrist function (16). Forearm rotation is neutral in the "thumb-up" position, halfway between pronation and supination. The forearm usually supinates 85° and pronates 75° (17).

Pathomechanics

The radiocarpal, midcarpal, and DRUJ mechanism change after distal radius injuries (18). The normal mechanics of wrist joint are impacted by distal radius deformity, which results in a restriction of the extension-flexion range of motion. The normal load transmission across the entire wrist joint is impacted by malalignment. The wrist's axial loading is shifted dorsally and ulnarly by the dorsal tilting of the distal radius, which reduces the joint contact area and may cause midcarpal instability. That might be a sign of pre-arthritis in the wrist joint (19, 20). Radial shortening may affect DRUJ and reduce radioulnar contact area, limiting supination-pronation and causing early arthritis (21, 22).

Mechanism of Injury

Injuries sustained during athletic participation, falls from a height, and MVAs were the most frequent injury mechanisms in young patients. Elderly people can get distal radial fractures from low-velocity injuries (23). The most frequent method of injury was from falling on an outstretched hand (FOOSH) with dorsiflexed wrist (24).

Patients and Methods

A prospective pre-post quasi experimental study was involving 20 patients (16 male, 4 female) and within 6 months of follow-up between October 2021 and May 2022 who were admitted to Orthopedic Department in Port Said General Health Insurance Hospital. This research found that FOOSH was the most frequent cause of trauma.

Inclusion criteria and Exclusion criteria

This study includes patients with multi-fragmentary and intra-articular fractures with step off above 2 mm who were skeletally mature and between the ages of 18 and 60.

The study excludes participants with paralysis of a limb, inflammatory arthritis, pathological fractures, associated fractures of radius (segmental), open fractures of distal radius of Gustilo and Anderson types II and III, or neurovascular injury.

On admission

History taking and clinical examination were done for all patients, pre-fracture level of activity was assessed, radiological assessments (plan x ray in A-P, lateral and oblique views) of the affected limb for determining the direction of displacement and the fracture pattern. Full laboratory investigations were also performed. CT scan of affected limb to evaluate lunate fossa, radio ulnar incongruity and number of broken fragments.

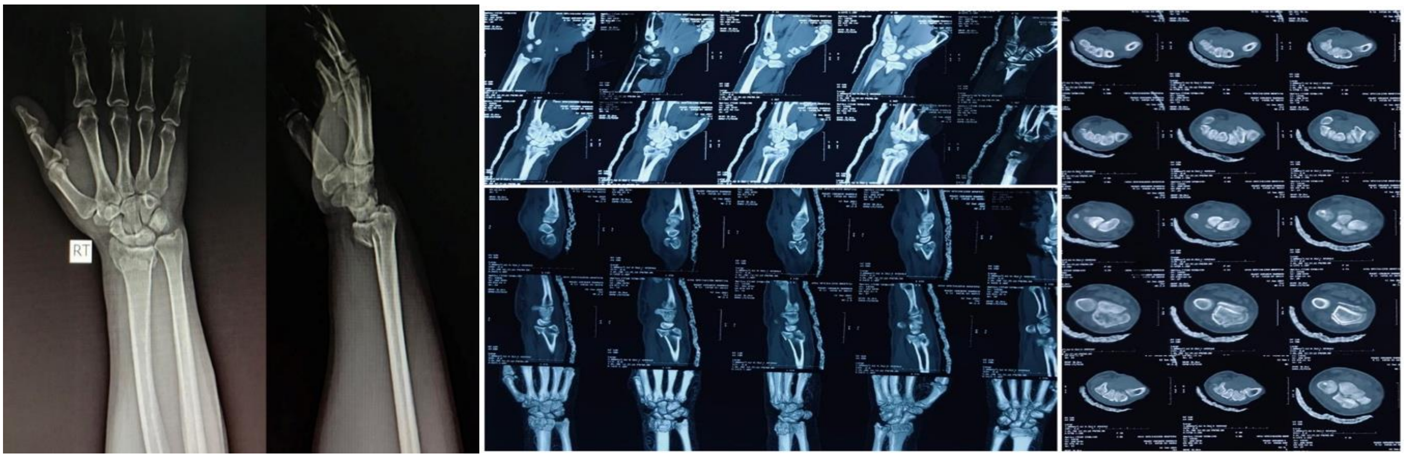

Figure (1): Preoperative X-ray and CT scan

Anesthesia

After general anesthesia and prophylactic antibiotics, the tourniquet was inflated, and the surgical site was cleaned and sterilized.

Position: The patient abducted his shoulder to place his forearm on a hand table in a supine position. The surgeon was sitting on the affected side of the hand table.

Approach and Procedure: Using a modified Henry incision, a volar approach was made to distal radius over flexor carpi radialis tendon. The FCR tendon was exposed through a skin incision that is 8-10 cm long [25]. Dissecting the flexor pollicis longus lower to distal radius. The flexor pollicis longus muscle was exposed more. Blunt dissection with an L-shaped incision exposes pronator quadratus muscle and anterior wrist capsule, revealing the fracture site. Simple wrist traction, slight palmar flexion, and manual manipulation was used to diminish the fracture and stabilize it with k-wires under the C-Arm.

Plate Position: The plate was put close to the Watershed line. To ensure the position, K-wires were inserted in it. C-arm imaging shows that the plate was elongated on its ulnar side. If the distal radius fractured ulnarly, the plate may be ulnar or distal over the fracture line to be covered. A screw was placed in the plate's oval, non-locking hole to finely adjust its proximal or distal position. At this stage, the plate was supporting the fragment of lunate facet. The plate will now serve as a buttress for fragments of lunate facet [26].

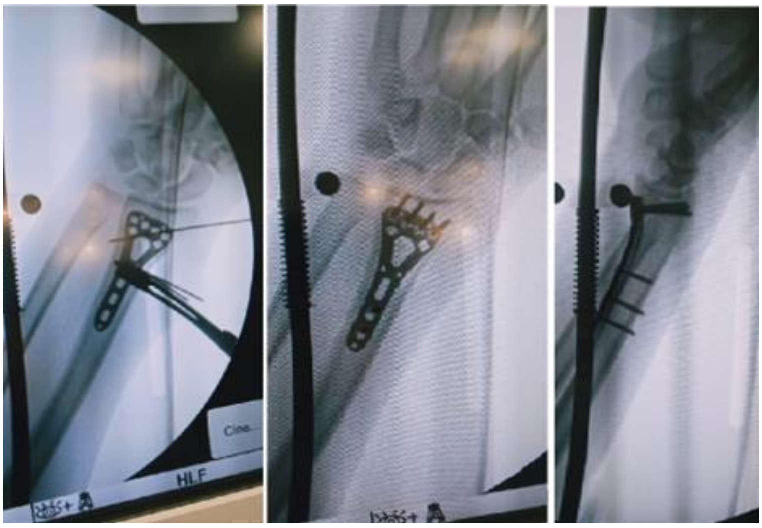

Figure (2): Intraoperative plate fixation

Wound Closure: In the event that it was repairable, pronator quadratus was sutured over the plate. Simple interrupted sutures were used to close the skin wound and subcutaneous layer. The patient was placed in a splint while ensuring fingers and Metacarpo-Pharyngeal Joint are free.

Post-Operative and Rehabilitation: The post-operative care was conducted, including NSAIDs, oral broad-spectrum antibiotics, and anti-edematous medications. Patients were permitted to wear wrist braces for an extra two weeks after splint removal at four weeks. Patients were told to partially wear a removable wrist brace while beginning gentle active wrist and finger exercises.

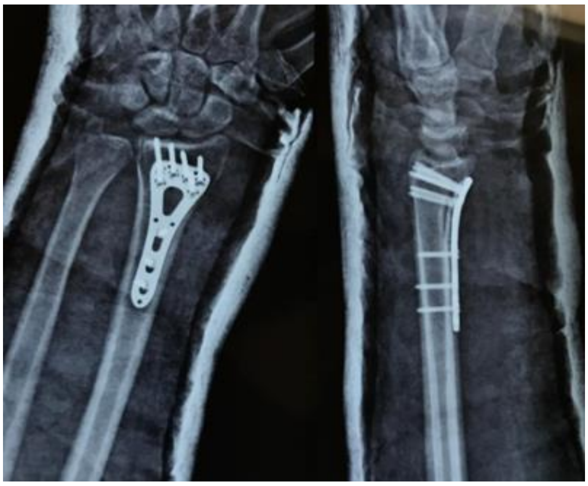
Figure (3): 1^{st} week Postoperative X-ray

Follow up: the first visit after a week for wound care and 1^{st} postoperative x-ray follow up, second visit after 2 weeks for stich removal and then after 4^{th} & 6^{th} weeks postoperatively for X-ray follow up. Standard AP & lateral radiograph was obtained with clinical assessment to exclude infection and tendon injuries.

After 6 weeks, the physiotherapist instructed the patients regarding the standard ROM exercises for the wrist and fingers.

Figure (4): 6^{th} week postoperative X-ray

At 3^{rd} and 6^{th} month full evaluation of ROM, modified MAYO wrist score, quick DASH score and radiological parameters will be obtained as a final evaluation after full fracture consolidation which was used for statistical analysis.

Figure (5): 3^{rd} &6^{th} month follow-up

statistical evaluation and interpretation of the data

Data analysis was performed by SPSS software, version 25 (SPSS Inc., PASW statistics for windows version 25. Chicago: SPSS Inc.). Number and percentage were used to describe the qualitative data. The median value (min. and max.) was calculated using the Kolmogrov-Smirnov test to determine whether the quantitative data were normally distributed. The data were described using mean and standard deviation for normally, and for non-normally distributed data. The (0.05) level was used to estimate the significance of results. The paired t test was used for comparison of two pairs of readings when data were regularly distributed.

Result

Table (1): Outcome results for Polyaxial plate fixation at 3^{rd} and 6^{th} month. The mean of age was 37.35 years ranging from (19-60) years, 80% are males and 65% smokers. 40% of class C3, 35% class C2 & 25% class C1. 85% of the studied cases have right sided lesion and 15% left sided lesion, 75% right dominant hand & 25% left dominant hand. Mode of injury distribution among studied cases was 55% FOOSH, 20% direct trauma, 10% falling from height, 10% RTA and 5% MVA. The median time to surgery was 3 days ranging from (1-7) days, the median operative time was 70 minutes ranging from (60-110) minutes. 13 smokers (65%) showed prolonged union time above 8 weeks with statistically significant result of 30% of delayed union with mean (8.5) weeks related to all smokers within the sample. While mean union time was 6.50±0.85 (5-9) weeks.

Radial height, radial inclination, and volar tilt measurements taken after three months, and six months of treatment did not differ statistically from each other. The radial height range (6–12 mm), volar tilt range (8–12 degrees), and radial inclination range (18–23 degrees) at the final follow-up. A statistically significant improvement in flexion degree changed from 65% of cases with limited flexion after 3 months that decreased to 25% after 6 months.

Similarly, a statistically significant improvement in extension degree that changed from 25% of cases have limited extension range after 3 months that decreased to 20% after 6 months.

A statistically significant improvement in radial deviation that changed from 40% of cases have limited radial deviation after 3 months that decreased to 25% after 6 months. Similarly, a statistically significant improvement in ulnar deviation total score from 31.5 to 33, while total limited ROM cases was the same for both follow up periods (4 cases each).

Statistically significant improvement in Q-DASH score. After 3 months of treatment; 50% of cases have excellent Q-DASH and 50% good. After 6 months; 55% excellent and 45% good Q-DASH score. there is no statistically significant difference of MAYO score between 3&6 months follow up after treatment with the following distribution: 55% excellent, 30% good & 15% satisfactory after 3 months of treatment that changed to 55% excellent, 35% good & 10% satisfactory after 6 months of treatment.

Complications of Polyaxial Plate Fixation

Statistical analysis of complications for volar locking plate fixation shows no significant identified related to hardware. (**Table: 2**)

One patient (5%) developed carpal tunnel syndrome that responds with medical treatment for 3 weeks. One (5%) develops Limited ROM received extensive physiotherapy sessions. One case (5%) with uncontrolled diabetes was presented with superficial wound infections which were resolved with regular dressings and oral intake of antibiotics for two weeks. One case (5%) with dorsally penetrating screw and extensor indicis rupture underwent secondary surgeries for screw perforation removal and tendon suture repair.

Table (2): Incidence of complications among studied cases.

	Number	**%**
None	16	80.0
Carpal tunnel syndrome	1	5.0
Extensor Indexis rupture	1	5.0
Limited ROM	1	5.0
Superficial skin Cellulitis	1	5.0

Discussion

Variable angle locking plates are used for intra-articular distal radius fractures fixation, according to cadaveric research. ***Sascha Rausch et al,*** [27] found that these plates have higher construct stiffness and superior properties under cyclic loading than monoaxial fixed angle plates, the two column plate constructs with volar angle locking plate (VALP) revealed significantly greater initial and final stiffness (**P**=0.008 and **P**=0.006 respectively) than did the constructs involving fixed-angle locking. The conventional-plate designs had a mean reduction of 0.9 mm (SD 0.5 mm) compared to 0.3 mm for the Polyaxial plate constructs (P=0.032) (SD 0.26mm) [27].

The average period of follow-up in this research lasted six months. Similar to what Khatri et al. [10] reported, the average follow-up time was 11.042.47 months (6-15). While ***Mehrzad and Kim et al,*** [28] the mean follow-up duration was 44 months with a range of (32 – 65) months. ***khatri et al,*** [10] discovered that the average loss in radial length (P>0.13), radial inclination (P>0. 0.095), and volar angle (P>0.13) at the end of follow-up were statistically insignificant results when compared to the immediate post-operative follow-up. Similar to this, in our study, radial height, radial inclination, and volar tilt measurements at the third- and sixth-month follow-up showed a statistically insignificant difference (p=0.01).

According to MAYO (**p**=0.33) and Q-DASH score (p<0.001) in our study, showed a statistically significance results at the end of follow up. When we compare our study with ***Marlow WJ***, [29] which was a retrospective included total 107 patients, of these 65 underwent variable angle plate fixation (group V) and 42 underwent fixed angle plate fixation (group F) with all types of distal radial fractures. Q-DASH score (**p**=0.225) and MAYO (**p**= 0.063) there was no statistically significant difference for each group. At the end of follow up as regard to Q-DASH scoring system in our study, 11 patients (55%) had excellent results, 9 patients (45%) had good results and no cases had poor results with a mean Q-DASH score of (6.25±3.43). ***Figl et al,*** [30] showed perfect results in (37.5%) of patients, good results in (67%), and fair results in 1% in patients treated with VALP. Objective range of movement in each direction was recorded. Having a superior range of movement which was statistically significant in flexion (**p**<0.001), extension (**p**<0.001), ulnar deviation (**p**=0.01) and radial deviation (**p**=0.004). As reported by ***Marlow WJ,*** [29] having a superior range of movement which was statistically significant in the case of ulnar deviation (**p**= 0.002) for Polyaxial plate. This might be connected to the Polyaxial's design, which enables the fixation of fractures with multiple fragments and reconstruction of intricate geometry of the distal radius articular surface.

Smoking has a statistically significant influence in union time. Nonsmokers achieved more satisfactory results in union time than the smokers. In our study, the mean union time was 6.50±0.85

(5-9) weeks. Smokers represent 65% of patients and show statistically significant result of 30% of delayed union with mean (8.5) weeks (**p**<0.05). ***Daniel Hess et al,*** [31] *found 9.8% of smokers had complications compared to 5.6 percent of nonsmokers*. Smokers had significantly elevated rates of hardware removal (P<0.05), nonunion (P<0.003), revision procedures (P<0.05), wrist stiffness (P<0.05), and distal radius tenderness (P<0.05) compared with the nonsmoking group.

In our series, one patient (5%) developed carpal tunnel syndrome, one (5%) developed Limited ROM, one patient (5%) with superficial wound infections, one patient (5%) presented with extensor indicis rupture with a secondary repair. There were no intraarticular screw perforation (radiocarpal or radioulnar) complications. Due to the plate's low profile compared to the conventional 3.5 mm method, they can be put more distally for subchondral fixation and less tendon and soft tissue irritation. As reported by ***Mehrzad and Kim,*** [33] that 4 cases had secondary carpal tunnel release. No VALP hardware-related issues occurred. The 3 fracture types for Polyaxial group patients had no statistically significant variation in rate of complication (**P**=0.98). While for uniaxial group, 7 patients suffered hardware-related issues, resulting in a 12 percent complication rate, significantly elevated (P<0.001) than Polyaxial locking plate group.

CONCLUSION AND RECOMMENDATION

Biomechanically sound Polyaxial locking plates treat intra-articular distal radius fractures. With these plates, screws can be inserted at a variety of angles, and the plate position can be adjusted to accommodate volar fracture lines, reducing the risk of screw perforation by directing screws away from the joint. A better fracture fragment buttress can be offered by the variable angle system's flexibility. Furthermore, the screw direction can be modified to fit particular fracture fragments.

Polyaxial plates performed better in this investigation. According to low-profile material, hardware did not cause issues or reoperations.

We recommend for further studies to consider the following items: larger sample size, prolonged follow-up period, other confounding variables like age and sex with their relation to delayed union and nonunion, recording further complications related to smoking and the relation between radiological and functional end results, to check if the functional outcomes match their outstanding radiological results.

Table (1): clinical result for Polyaxial plate fixation for 3rd and 6th month.

Group	Age	Time to surgery (days)	Flexion		Extension		Radial deviation		Ulnar deviation		MAYO		Q-DASH		Radial Hight	Radial Inclination	Volar Tilt
			3rd month	6th month	3rd month	6th month	3rd month	6th month	3rd month	6th month	3rd month	6th month	3rd month	6th month			
N	20	20	20		20		20		20		20		20		20	20	20
Median	37.35 (19-60)	3.00	52.75	61.75	58.50	56.00	18.95	21.0	31.50	33.0	84.75	85.0	6.95	6.25	9.75	20.60	10.15
Percentiles	0.0	0.0	17.1%		16.1%		10.8%		4.8%		0.2%		10.1%		0.0	0.0	0.0
test of significance	t=0.0	t=0.0	t=4.49 p <0.001*		t=4.41 p <0.001*		t=3.32 p=0.004*		t=2.85 p=0.01*		t=1.0 p=0.33		t=5.48 p<0.001*		t=0.0	t=0.0	t=0.0

References

1. Browner B, Levine A, Jupiter J, et al. (2003): Skeletal Trauma. Basic Science, Management and Reconstruction, 3rd edition. Saunders, USA; 80(4): 74–82.
2. McFadyen I, McCann P, et al. (2011): Should unstable extra-articular distal radial fractures be treated with fixed volar locked plates or percutaneous K-wires? A prospective randomized controlled trial, Int. J. Care Injured; 42(2): 162–66.
3. Bentley G (2009): European Instructional Lectures, vol. 9, 10th Effort Congress, Vienna, Austria: Springer Science; 20(1): 94–104.
4. Wilcke MKT, Hassan Abbasside and Adolphson PY (2011): Wrist function recovers more rapidly after volar locked plating than after external fixation but the outcomes are similar after 1 year. A randomized study with a dorsally displaced fracture of the distal radius, Francis: Taylor, Acta Orthopaedica; 82(1): 76–81.
5. Dicpinigaitis P, Wolinsky P, Hiebert R, et al. (2004): Can external fixation maintain reduction after distal radius fractures? LWW, Journal of Trauma and Acute Care Surgery; 57(4): 845-50.
6. Blakeney, William G (2010): Stabilization and treatment of Colle's fractures in elderly patients: Dove Press, Clinical interventions in aging; 18(5): 337-44.
7. Osada D, Viegas SF, Shah MA, et al. (2003): Comparison of different distal radius dorsal and volar fracture fixation plates: a biomechanical study: Elsevier. J Hand Surgery; 28(1): 94–104.
8. Khamisy S, Weil YA, Safran O, et al. (2011): Outcome of dorsally comminuted versus intact distal radial fracture fixed with volar locking plates: Elsevier. Int. J. Care injury; 42(4): 393-96.
9. Ross M and Heiss-Dunlop W (2009): Volar angle stable plating for distal radius fractures: Saunders. Slutsky DJ; 126-39.
10. Khatri K, Sharma V, Farooque K, et al. (2016): Surgical Treatment of Unstable Distal Radius Fractures with a Volar Variable-Angle Locking Plate: Clinical and Radiological Outcomes: Brieflands. Archives of Trauma Research; 5(2): 25-74.
11. Nordin, Margareta, and Victor Hirsch Frankel (eds). (2001): Basic biomechanics of the musculoskeletal system, Nordin Basic, 4th ed. Philadelphia: Lippincott Williams & Wilkins; 365-94.
12. Crisco JJ, Heard WM, Rich RR, et al. (2011): The Mechanical Axes of the Wrist Are Oriented Obliquely to the Anatomical Axes. The Journal of Bone and Joint Surgery. American volume; 93(2): 169–77.
13. Neumann, Donald A (2016): Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation, 2nd ed. St Louis; MO: Mosby Elsevier Health Sciences; 7: 216-43.
14. Tang, Jin Bo R, Jaiyoung O, et al. (1999): Biomechanical evaluation of wrist motor tendons after Fractures of the distal radius: Elsevier. J Hand Surgery; 24(1): 121-32.
15. Fernandez DL (1988): Radial osteotomy and Bowers arthroplasty for malunited Fractures of the distal end of the radius: LWW. J Bone Joint surgery; 70(10): 1538-1551.
16. Nijs S and Broos PL (2004): Fractures of the Distal Radius: a Contemporary Approach: Taylor & Francis. Acta Chirurgica Belgica; 104(4): 401-12.
17. Thompson, David M (2003): Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation, 2nd ed: Oxford University Press. Physical Therapy; 83(4): 402.
18. Hutchinson 3rd, F (1995): Malunions of the distal radius: Treatment options. Journal of the Southern Orthopaedic Association; 4(1): 53-68.
19. Miyake T, Hashizume H, Inoue H, et al. (1994): Malunited Colle's fracture Analysis of stress distribution. The Journal of Hand Surgery [British&European]; 19(6): 737-42.
20. Foldhazy Z, Tornkvist H, Elmstedt E, et al. (2007): Long-term outcome of non-surgically treated distal radius fractures: Elsevier. The Journal of Hand Surgery [Am]; 32(9): 1374-1384.

25. Bronstein AJ, Trumble TE, Tencer AF (1997): The effects of distal radius fracture malalignment on forearm rotation: A cadaveric study. The Journal of Hand Surgery; 22(2): 258-62.

22. Mifsud C and Drew T (2015): Pathomechanics of the wrist following fractures of the distal radius. SAGE Publications Sage UK: London, England. The Journal of Hand Therapy; 20(1): 11–23.

23. Koo, Kevin OT, David MK Tan, et al. (2013): Distal radius fractures: an epidemiological review: Wiley Online Library. Orthopaedic surgery; 5(3): 209-13.

24. Taleisnik, Julio (1976): The ligaments of the wrist, The Journal of hand surgery, Elsevier; 1(2):110-18.

25. Orbay JL, Badia A, Indriago IR, Infante A, Khouri RK, Gonzalez E, et al. The extended flexor carpi radialis approach: A new perspective for the distal radius fracture. Tech Hand Up Extreme Surg. 2001; 5(4):204–11.

26. Mohamed et al. Polyaxial Locking Plate in Fractures of the Distal Radius. Journal of Advances in Medicine and Medical Research. JAMMR, 2020; 32(22): 79-88.

27. Rausch S, Klos K, Stephan H, et al. (2011): Evaluation of a polyaxial angle-stable volar plate in a distal radius C-fracture model a biomechanical study. Injury Int J; 42(11): 1248–1252.

28. Mehrzad R, Kim DC (2016): Complication rate comparing variable angle distal locking plate to fixed angle plate fixation of distal radius fractures. LWW: J Annals of Plastic Surgery; 77(6): 623-25.

29. Marlow WJ, Singhal R, Dheerendra S, et al. (2012): Distal radius volar locking plates: does a variable angle locking system confer a clinical advantage? Acta Orthopædica Belgica; 78(3): 309-16.

30. Figl M, Weninger P and Liska M (2009): Volar fixed-angle plate osteosynthesis of unstable distal radius fractures: 12 months results. Archives of Orthopaedic and trauma surgery; 129(5): 661–69.

31.Hess, Daniel E., et al. (2020): "Smoking increases postoperative complications after distal radius fracture fixation: a review of 417 patients from a level 1 trauma center." Hand; 15(5): 686-91