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Surgical management of fractures of distal end radius with open reduction and internal fixation using volar locking compression plate

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Abstract
Backgrounds and Objectives: Fractures of distal end of the radius are one of the most common injuries which lead to approximately 1/6th of all fractures which are observed and treated.
Failure to achieve and also to maintain anatomic restoration may lead to various deformities and disabilities, poor functional outcome (usually seen with cast immobilization of intraarticular fractures)
Later studies have advised operative intervention with conventional T buttress plates, and more recently volar locking compression plates whose mechanical advantage justifies its vast usage.
The principle of the Locking Compression Plate is to have rigid fixation close to the bone and under the soft tissue envelope. Locking Compression Plates are anatomically designed plates to maintain alignment and to prevent collapse of the fracture fragment.
Methods: This study is a prospective, time bound, hospital based study that was conducted in kempegowda institute of medical sciences and research centre, Bangalore between October 2018 and May 2020. The study included a total of 30 cases of distal end radius fractures that were operated with open reduction and internal fixation with volar Locking Compression Plate (volar LCP).
The fractures were classified according to Frykmann classification and were followed up at regular intervals. Functional outcome was assessed using the Gartland and Werley demerit scoring at each follow up visit.
Results: Our study revealed nearly half of the study population with excellent outcome (47%), good and fair outcomes were noted among 40% and 13% respectively while none of the patients had poor outcome.
Most fractures united by 12 weeks. Complications associated were stiffness, arthritis and EPL tendon irritation.
Conclusion: The present study demonstrates well to excellent results in the majority of patients based on G&W functional outcome evaluation after locking plate fixation of the lower end distal radius with lower rate of complications.

Keywords: Distal end radius, comminuted, intra-articular, open reduction, internal fixation, locking compression plate

Introduction
Distal radius fractures crush the mechanical foundation of the man's most elegant tool, the hand. No other fracture has a greater potential to devastate hand function, and no other metaphysis of bone is embraced by more soft tissues. Fractures of the distal radius are among the most common fractures of the upper extremity and account for approximately one sixth (16%) of all fractures seen and treated in emergency rooms [1-3].
Fractures of the distal radius have traditionally been discussed with reference to the eponyms Colles, Pouteau, Smith and Barton. However, it is more important today to determine the nature of the fracture and to describe the pathology involved, than to link diagnosis and treatment to a specific name. The type, direction and amount of displacement are the most important factors relating to treatment [4].
It is now generally accepted that for the ventral Barton fractures and for Smith fractures, internal fixation is indicated as these fractures are always articular and are associated with actual or potential subluxation or dislocation of the carpus with a distal fracture fragment [5].

Regarding Colles fracture however, there still is a lot of discussion. In 1940, Sir Reginald Watson Jones claimed that it must always be remembered that a Colles fracture, if left untreated, usually results in a fully functioning hand and forearm, albeit with displacement and some limitation in movement [6].

It is important therefore to ensure that whatever treatment is given, the end result is better than leaving the fracture alone. In 1960, Sir John Charnley wrote : 'It is a fortunate thing that excellent functional results usually follow the common Colles' fracture, because disappointing results occasionally develop even in the most skilful hands' [7].

It is now realized that many patients after distal radius fractures definitively do not enjoy perfect freedom in all wrist movements and that they are definitely not exempt from pain even after many months [8].

Even though these fractures are so common, significant controversy exists concerning the best method of treatment. Over the last 20 years there has been a significant rise in the interest level and understanding of the importance of treatment of distal radius fractures [9].

Many fractures of the distal aspect of the radius are in fact relatively uncomplicated and are effectively treated with closed reduction and immobilization in a cast. However, fractures that are either comminuted and/or involve the articular surfaces can jeopardize the integrity of the articular congruence and/or the kinematics of these articulations.

Various methods have been used historically to treat fractures of the distal radius. The first andby far the most frequently used method has been closed reduction and plaster cast immobilization. This treatment has been applied for many years, but it has recently received a lot of criticism, especially for the more complex fractures [10-12].

The goal of the treating physician should then be to restore the functional anatomy by a method that does not compromise hand function. The fracture pattern, the degree of displacement, the stability of the fracture, and the age and physical demands of the patient determine the best treatment option.

The use of percutaneous pin fixation; external fixation devices that permit distraction and palmar translation; low-profile internal fixation plates and implants; arthroscopically assisted reduction; and bone-grafting techniques including bone-graft substitutes, all have contributed to improved fracture stability and outcome.

Over the past twenty years, more sophisticated internal and external fixation techniques and devices for the treatment of displaced fractures of the distal end of the radius have been developed.[13]Established treatment options comprise closed reduction and cast stabilization, external fixation, and open reduction with internal plate fixation (ORIF). The first two options may be combined with percutaneous K-wire pinning.

Closed reduction and percutaneous pinning has been popular for many years and continues to be one of the most popular techniques internationally. The pinning can be of several varieties, including Clancey pinning (that is, 0.062-inch wires into the radial styloid and the dorsal ulnar corner of the radius, crossing the fracture site) and Kapandji pinning (that is, wires or arum pins placed into the fracture site dorsally and used as levers to reduce the fracture and then to stabilize it) [14].

In recent years, angle-stable, volar locking plates have been propagated and enthusiastically used for surgical fixation of distal radial fractures, especially in the osteoporotic bone. The underlying biomechanical principle of angle-stable locked plating is that uni-cortical, threaded screws fixed in the screw hole of the plate ("internal fixator") reduce shear forces, thereby preventing loosening of the surgical construct. However the available clinical evidence in favor of this principle is limited to case series of moderate to poor quality [15-20].

The distal radius fractures especially the high energy fractures are often associated with poor results and high complication rates [3]. The method of immobilization that maintains the reduction with the least amount of surgical morbidity is the ideal treatment. Unstable fractures of the distal part of the radius have shown an inherent tendency toward loss of reduction after non-operative treatment. External skeletal fixation has been popular for the treatment of displaced, unstable fractures of the distal part of the radius because it combines a minimally invasive procedure with reduction by ligamentotaxis [21].

However, despite the frequency of distal radius fractures, the optimal treatment remains without consensus opinion. A doubling incidence of surgical treatment for distal radius fractures and a more than 13-fold increase in the incidence of open reduction and plate fixation were observed. Factors such as number of years in practice, practice type, and the particular type of training received contributed most heavily to whether the fracture received internal fixation [22].

Overall, there is a trend toward increased distal end radius fractures toward open reduction and internal fixation has been identified with biomechanical and clinical studies suggesting treatment advantages of certain fixation methods over others but well-controlled patient trials are still missing to lend objective findings to management algorithms.

Preservation of the articular congruity is the principle prerequisite for successful recovery. The best method of obtaining and maintaining an accurate restoration of articular anatomy however, remains a topic of considerable controversy [23].

Considering the high frequency of distal end radius fractures and scarcity of data regarding the optimal treatment, the present study was undertaken to assess functional outcome of fractures of lower end radius treated with surgical management with LCP followed by early mobilization of wrist joint.

The objectives of the study were to assess functional outcome of fractures of lower end radius treated with surgical management with locked compression plate (LCP) followed by early mobilization of wrist joint.

Materials and Methodology

Source of data

The study was conducted in the Department of Orthopaedics, Kempegowda institute of medical science and research centre, Bangalore. All patients visiting the outpatient department and emergency department of the hospital were considered. Patients diagnosed with distal end radius fractures who were operated during the time period of October 2018 – May 2020 were included in the study. Patients were followed upto 15 months. Only post traumatic fractures were included while pathological fractures were excluded.

Sample Size

30 cases of distal end radius fractures were taken up for the study at Kempegowda institute of medical science and research centre, Bangalore

Study Period

October 2018 – May 2020

Study Method
Prospective study

Method of collecting data
All cases presenting to the outpatient and emergency department fulfilling the below mentioned criteria were recruited for the study.

Inclusion Criteria
- Fractures of distal end radius of either side.
- AO MULLER 23 A1, A2, A3, B1, B2, B3, C1, C2, C3.
- For fixation of complex intra and extra articular fractures.
- Age between 18-70 years.

Exclusion Criteria
- Pathological fractures.
- Polytrauma patients.
- Skeletally immature patients.
- Non union and delayed union.
- Fractures older than 2 weeks.

Surgical Procedure
The operations were performed under general anaesthesia in all cases and brachial block in 4 cases. The patient was placed supine on the operating table. The affected limb was elevated for 2-3 minutes and exsanguinated. Then a mid-arm pneumatic tourniquet was applied and the limb was placed on a side arm board. Forearm and hand were thoroughly scrubbed, painted with betadine and spirit and draped.
The incision for volar fixation of the distal radius is typically performed through the distal extent of the Henry's approach. An incision is made between the flexor carpi radialis (FCR) tendon and the radial artery. This interval is developed, revealing the flexor pollicis longus (FPL) muscle at the proximal extent of the wound and the pronator quadratus muscle more distally. The radial artery is carefully retracted radially, while the tendons of the flexor carpi radialis (FCR) radially and flexor pollicis longus (FPL) ulnar side.
After the pronator quadratus has been divided and elevated, the fracture is readily visualized, and reduction maneuvers can be accomplished under direct vision.
After exposure and debridement of the fracture site, the fracture is reduced and provisionally fixed under fluoroscopy with K-wires, reduction forceps or suture fixation. Reduction aids should be placed so as not to interfere with placement of the plate. The appropriate plate is selected following fracture reduction.
First, a standard cortical screw was applied to the most distal oval hole of the vertical limb of the plate in order to temporarily secure the plate to the proximal fragment. This allowed concomitant proximal and distal plate adjustment. After fixing the distal fragment with subchondral locking screws, radial length was gained, when necessary, by pushing the plate distally. The first standard screw can be either left in situ or exchanged with another locking screw.
The optimal placement of the distal screws is important. They must be inserted at the radial styloid, beneath the lunate facet, and near the sigmoid notch. The distal screws can be of either monocortical or bicortical engagement. More volar tilt can be achieved during distal screw placement when the wrist is volarly flexed as much as possible by an assistant. The final position of the plate was confirmed using fluoroscopy.
Pronator quadratus muscle was used at the time of closure, to cover, in part, the implants that were applied to the anterior surface of the radius.
Once stable fixation was achieved and hemostasis secured, the wound was closed in layers and sterile compression dressing was applied. The tourniquet was removed and capillary refilling was checked in the fingers. The operated limb was supported with an anterior below elbow POP slab with the wrist in neutral position.

Postoperative Care
Patient's vitals were monitored. Suture removal was done on 12th day post operatively. POP slab was removed and patient discharged. Patient was advised physiotherapy exercises on discharge.

Follow Up
For all subjects, radiographs were performed at the end of six weeks, three months and six months follow-up. Patients were evaluated based on the following parameters at the time of discharge and all the three follow ups;
- Range of motion
  - Wrist - Flexion, extension, supination, pronation, ulnar deviation and radial deviation
  - Elbow - Flexion, extension, supination and pronation.
- Complications - Arthritis, pain and EPL tendon irritation
- Clinical union
- Radiological union

Final outcome was calculated based on the Gartland and Werley demerit scoring system.

Results
This 1.5 year prospective study was conducted in the Department of Orthopaedics, Kempegowda institute of medical sciences, Bangalore from October 2018 to May 2020. A total of 30 cases who sustained fractures of lower end of radius were included in the study. The data was analysed and the observations were tabulated as below.

Table 1: Age Distribution among subjects

		Count	%
Age	20 - 30 Years	8	26.67%
	20.00%	6	20.00%
	41 - 50 Years	9	30.00%
	> 50 Years	7	23.33%
	Total	30	100.00%

In the Study, 26.67% were in 20 - 30 Years, 20.00% were in 20.00%, 30.00% were in 41 - 50 Years and 23.33% were > 50 Years. Mean age of subjects was 42.3 ± 15.18 years.

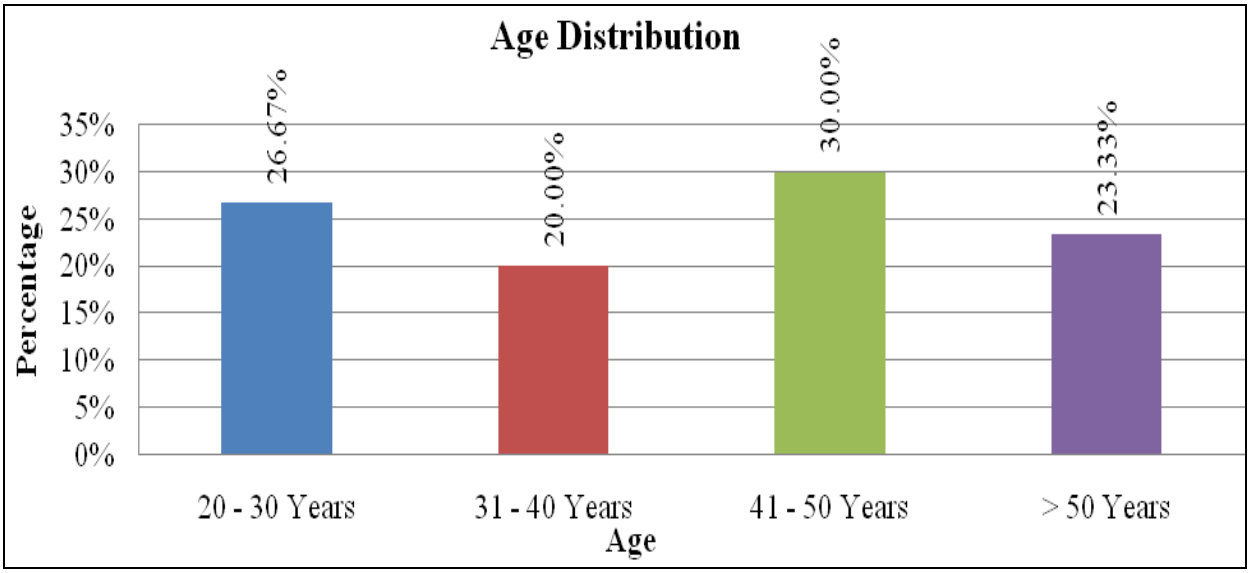

Fig 1: Bar Diagram Showing Age Distribution among subjects

Table 2: Sex Distribution among subjects

		Count	%
Sex	Female	13	43.33%
	Male	17	56.67%
	Total	30	100.00%

In the Study, 43.33% were Female and 56.67% were male.

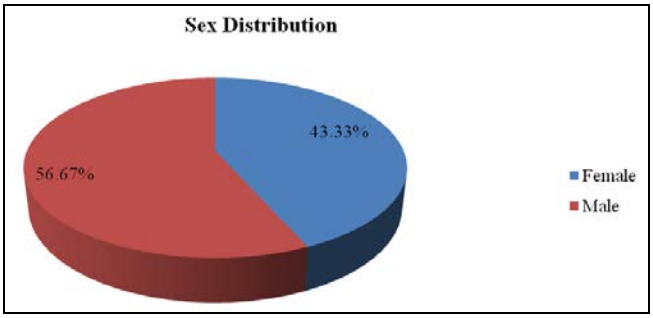

Fig 2: Pie Diagram Showing Sex Distribution among subjects

Table 3: Side Involved Distribution among subjects

		Count	%
Side involved	Left	16	53.33%
	Right	14	46.67%
	Total	30	100.00%

In the Study, 53.33% had injury in Left and 46.67% had in Right.

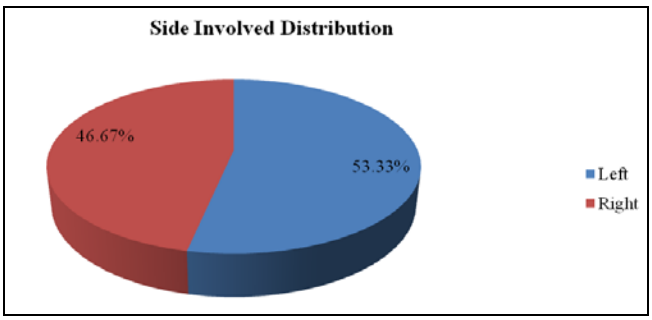

Fig 3: Pie Diagram Showing Side Involved Distribution among subjects

Table 4: Mode of Injury Distribution among subjects

		Count	%
Mode of Injury	FOOH	10	33.33%
	RTA	20	66.67%
	Total	30	100.00%

In the study, Mode of Injury in 33.33% was FOOH, 66.67% was RTA

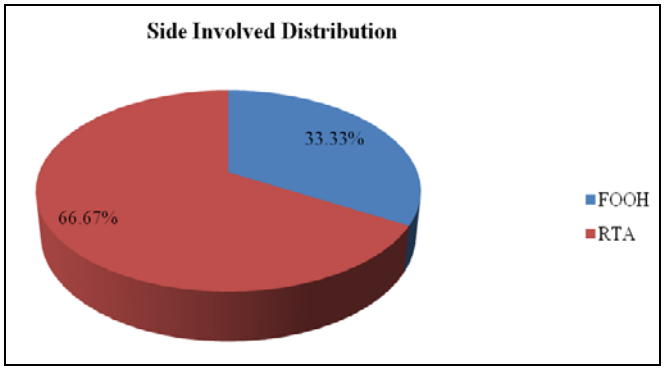

Fig 4: Bar Diagram Showing Mode of Injury Distribution among subjects

Table 5: Frykman/AO Type Distribution among subjects

		Count	%
Frykman/AO type	I/A2	4	13.33%
	II/A3	3	10.00%
	III/B3	6	20.00%
	IV/B2	3	10.00%
	V/B3	5	16.67%
	VI/C2	3	10.00%
	VII/C2	6	20.00%
	Total	30	100.00%

In the Study, Frykman/AO type I/A2 was 13.33%, II/A3 was 10.00%, III/B3 was 20.00%, IV/B2 was 10.00%, V/B3 was 16.67%, VI/C2 was 10.00% and VII/C2 was 20.00%.

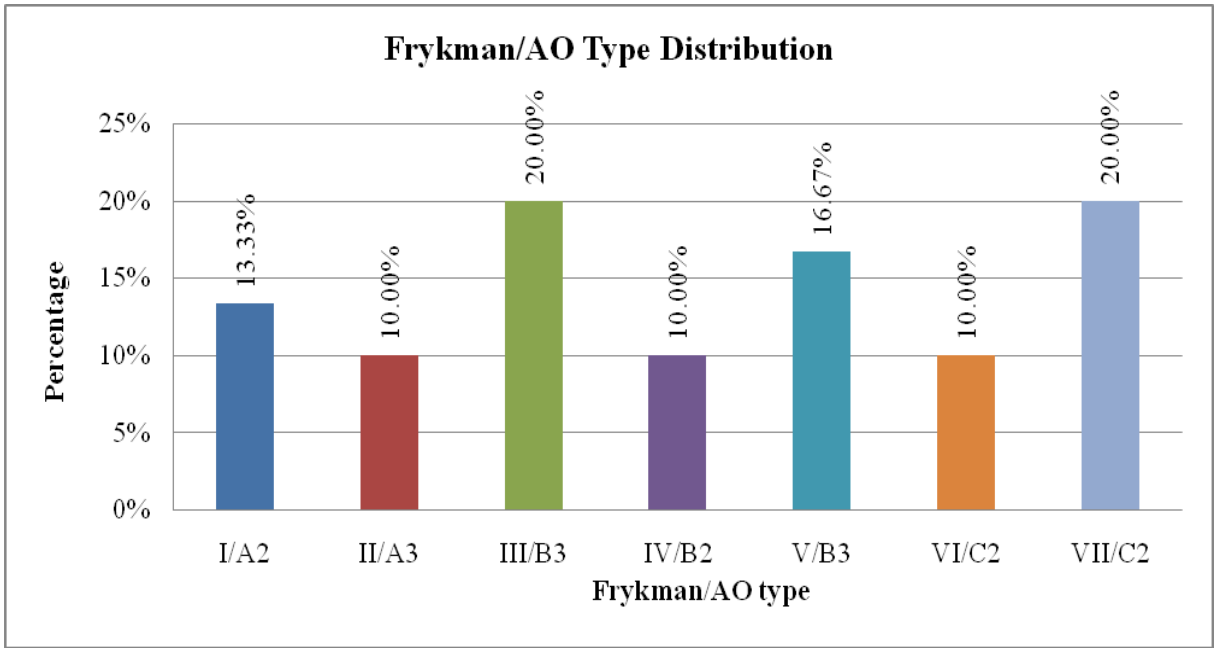

Fig 5: Bar Diagram Showing Frykman/AO Type Distribution among subjects

Table 6: Time from injury to surgery (days) Type Distribution among subjects

		Count	%
Time from injury to surgery (days)	1	16	53.33%
	2	10	33.33%
	3	3	10.00%
	4	1	3.33%
	Total	30	100.00%

In the study, 53.33% got surgery done in 1 day, 33.33% in 2 days, 10.00% in 3days and 3.33% in 4days.

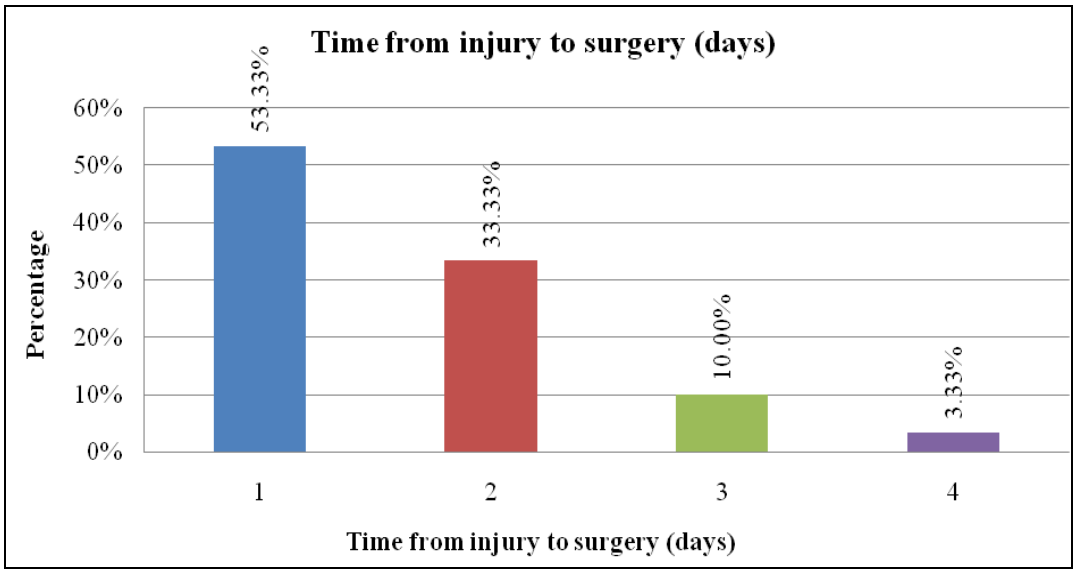

Fig 6: Bar Diagram Showing Time from injury to surgery (days) Type Distribution among subjects

Table 7: Duration of follow up months Type Distribution among subjects

		Count	%
Duration of follow up months	6	25	83.33%
	9	4	13.33%
	12	1	3.33%
	Total	30	100.00%

In the Study, 83.33% had follow up after 6months, 13.33% after 9months and 3.33% after 12 months.

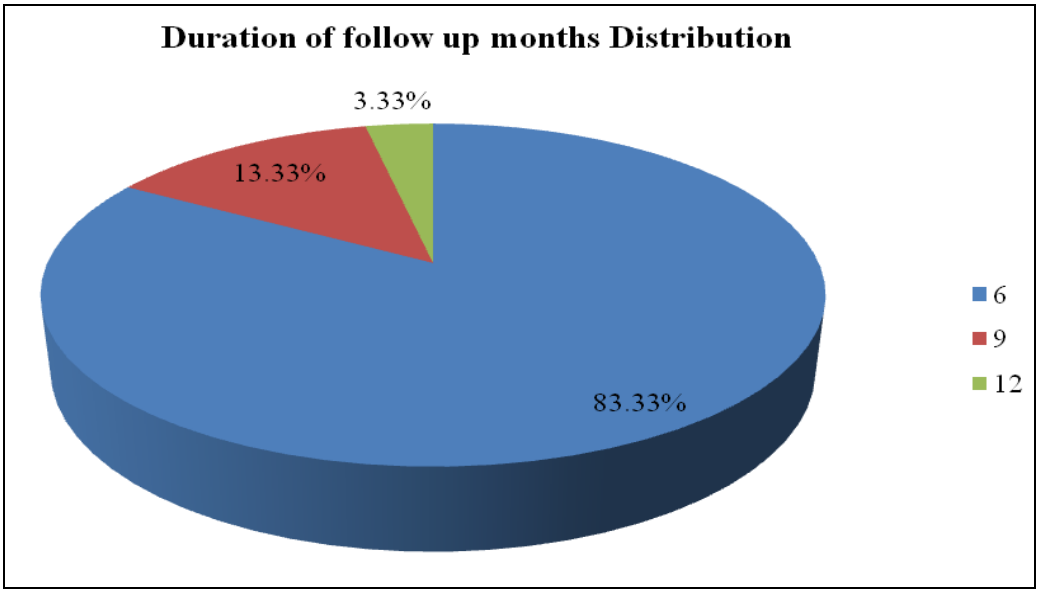

Fig 7: Pie Diagram Showing Duration of follow up months Type Distribution among subjects

Table 8: Mean Radial Length, Palmar Tilt and Articular Step off Distribution among subjects

	Mean	Median	SD
Radial length	8.87	9	1.36
Palmar tilt(degree)	5.77	7.5	4.61
Articular step off(mm)	0.33	0	0.66

In the study, Mean Radial length was 8.87 ± 1.36, Palmar tilt(degree) was 5.77 ± 4.61 and Articular step off(mm) was 0.33 ± 0.66.

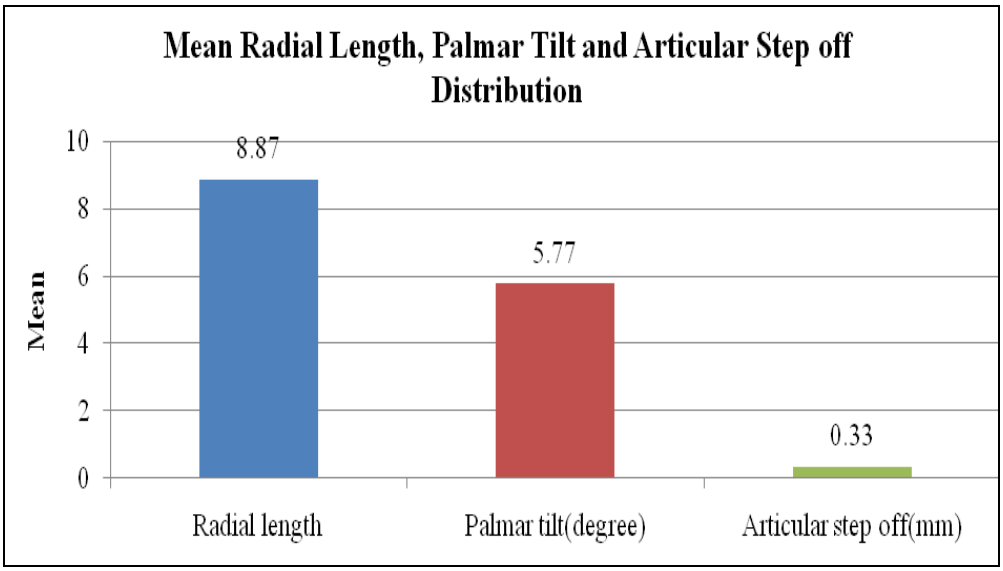

Fig 8: Bar Diagram Showing Mean Radial Length, Palmar Tilt and Articular Step off Distribution among subjects

Table 9: Mean Deformity Distribution among subjects

	Mean	Median	SD
Palmar flexion (PF)	70.83	75	9.83
Dorsiflexion (DF)	75.5	80	11.01
Radial deviation (RD)	13	15	3.37
Ulnar deviation (UD)	21.5	20	5.75
Supination	80.67	80	8.68
Pronation	73.67	75	10.08
G&W Score	4.67	4	3.43

In the study, Mean Palmar flexion (PF) was 70.83 ± 9.83, Dorsiflexion (DF) was 75.5 ± 11.01, Radial deviation (RD) was 13 ± 3.37, ulnar deviation (UD) was 21.5 ± 5.75, Supination was 80.67 ± 8.68, Pronation was 73.67±10.08 and G&W Score was 4.67 ± 3.43.

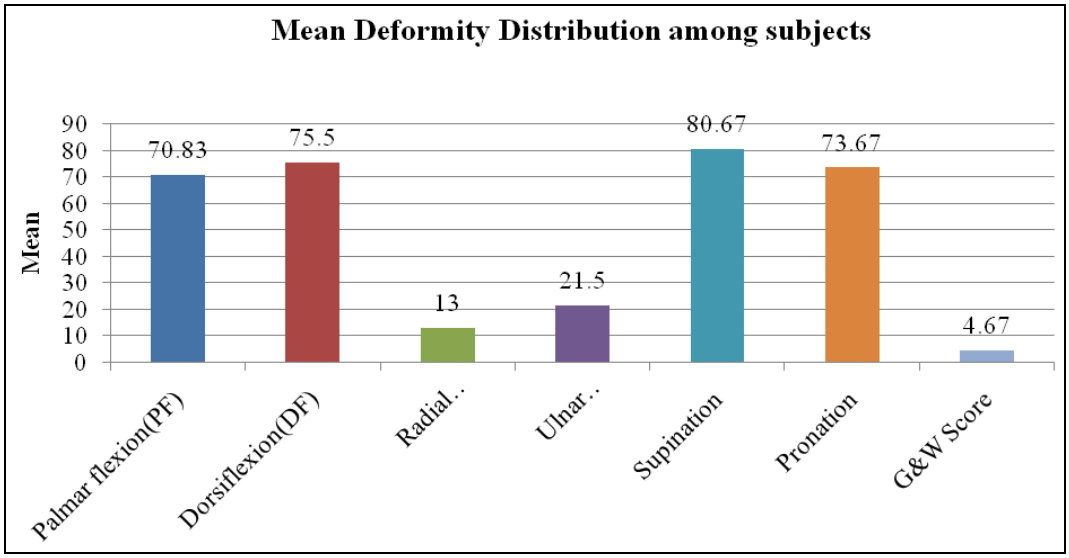

Fig 9: Bar Diagram Showing Mean Deformity Distribution among subjects

Table 10: Mean G&W Score Distribution among subjects

	Mean	Median	SD
G&W Score	4.67	4	3.43

In the Study, Mean G&W Score was 4.67 ± 3.43.

Table 11: Complications Distribution among subjects

		Count	%
Complications		28	93.33%
	Arthritis	1	3.33%
	EPL Tendon rupture	1	3.33%

In the Study, 3.33% had Arthritis and 3.33% had EPL Tendon rupture

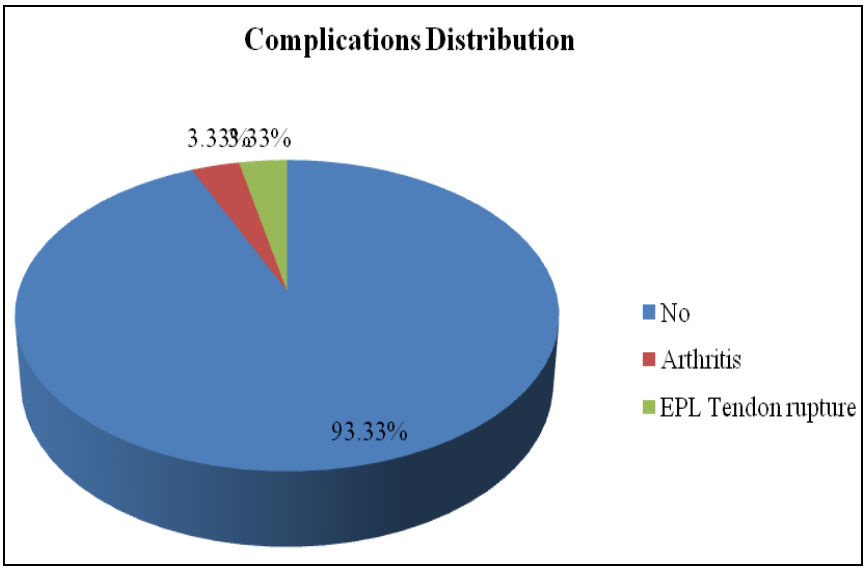

Fig 10: Pie Diagram Showing Complications Distribution among subjects

Table 12: Results Distribution among subjects

		Count	%
Results	Excellent	14	46.67%
	Fair	4	13.33%
	Good	12	40.00%

Results were Excellent in 46.67%, Fair in 13.33% and Good in 40%.

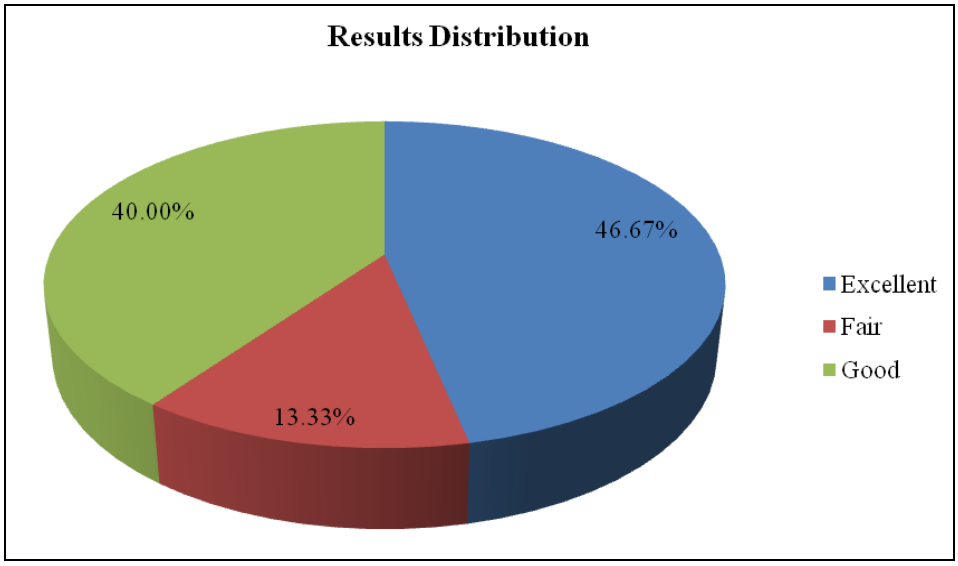

Fig 11: Pie Diagram Showing Complications Distribution among subjects

Table 13: Complications with respect to Duration of follow up months Distribution among subjects

		Duration of follow up months					
		6		9		12	
		Count	%	Count	%	Count	%
Complications		25	100.00%	3	75.00%	0	0.00%
	Arthritis	0	0.00%	0	0.00%	1	100.00%
	EPL Tendon irritation	0	0.00%	1	25.00%	0	0.00%

$\chi 2 = 36.696$, df = 4, p = < 0.001*

In the study, During 9th month follow up 1 had EPL Tendon irritation and at 12th month follow up 1 had Arthritis.

There was a significant difference in Complications Distribution with respect to Duration of follow up months.

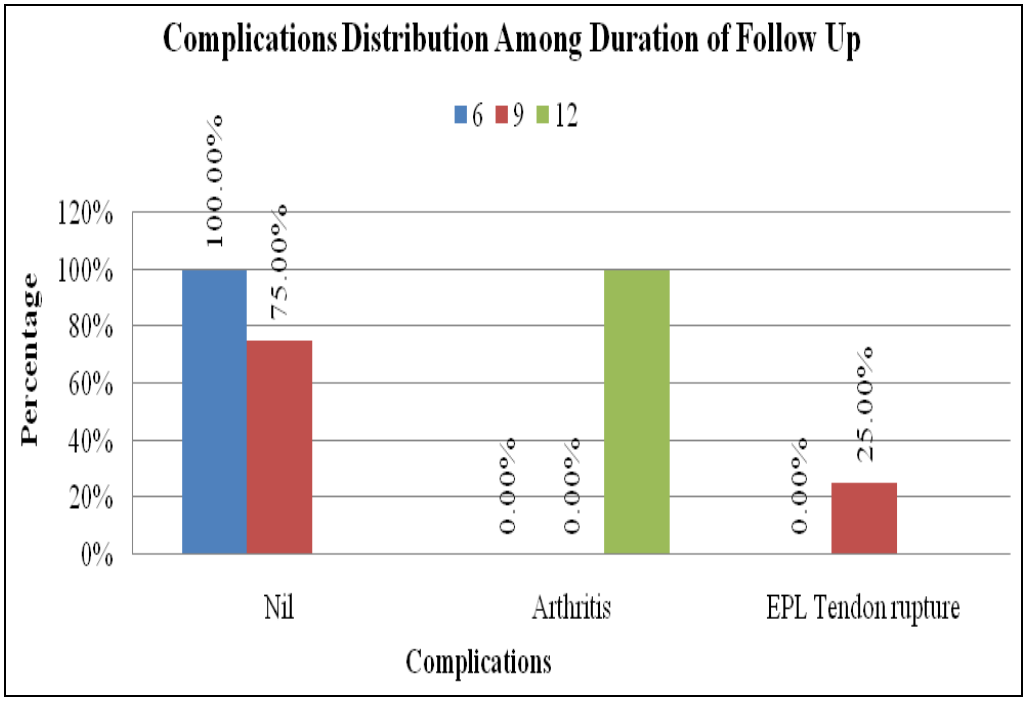

Fig 12: Bar Diagram Showing Complications with respect to Duration of follow up months Distribution among subjects

Table 14: Results with respect to Mode of Injury Distribution among subjects

		Mode of Injury			
		FOOH		RTA	
		Count	%	Count	%
Results	Excellent	5	50.00%	9	45.00%
	Fair	2	20.00%	2	10.00%
	Good	3	30.00%	9	45.00%

$\chi 2 = 0.911$, df = 2, p = 0.634

In the study, 50.00% had Excellent result in FOOH and 45.00% in RTA. 20% had Fair in FOOH and 10% in RTA.20% had Good Results in FOOH and 45% in RTA.

There was no significant difference in Results Distribution with respect to Mode of Injury among subjects.

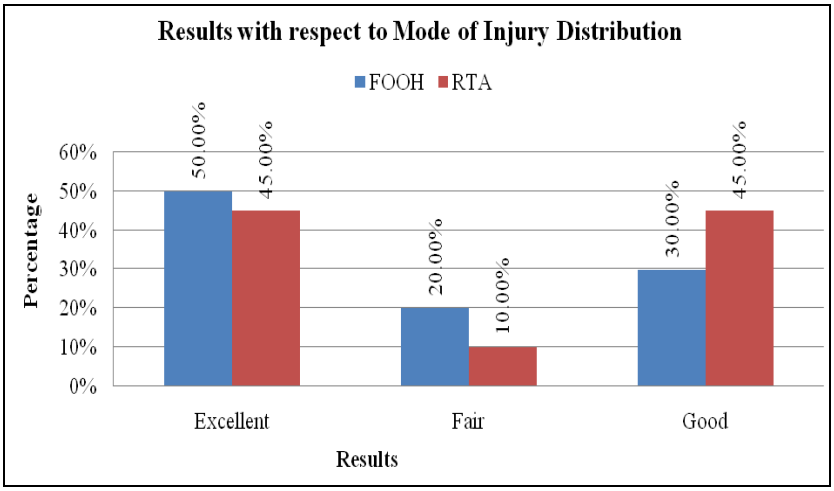

Fig 13: Bar Diagram Showing Results with respect to Mode of Injury Distribution among subjects

Table 15: Results with respect to Side Involved Distribution among subjects

		Side involved			
		Left		Right	
		Count	%	Count	%
Results	Excellent	9	56.25%	5	35.71%
	Fair	2	12.50%	2	14.29%
	Good	5	31.25%	7	50.00%

$\chi 2 = 1.349$, df = 2, p = 0.509

There was no significant difference in Results Distribution with respect to Side Involved among subjects.

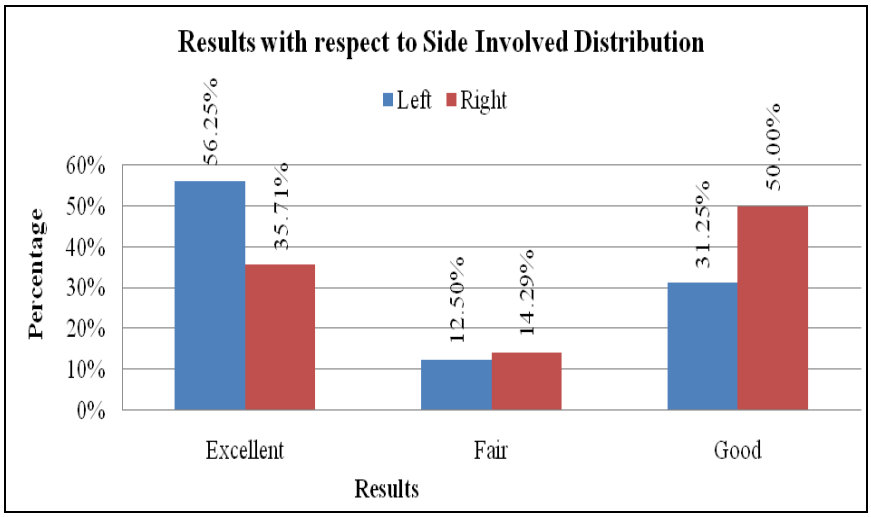

Fig 14: Bar Diagram Showing Results with respect to Side Involved Distribution among subjects

Table 16: Frykman/AO Type with respect to Results Distribution among subjects

		Results					
		Excellent		Fair		Good	
		Count	%	Count	%	Count	%
Frykman/AO Type	i/A2	1	7.14%	2	50.00%	1	8.33%
	ii/A3	1	7.14%	0	0.00%	2	16.67%
	iii/B3	4	28.57%	0	0.00%	2	16.67%
	iv/B2	0	0.00%	0	0.00%	3	25.00%
	v/B3	3	21.43%	1	25.00%	1	8.33%
	vi/C2	1	7.14%	0	0.00%	2	16.67%
	vii/C2	4	28.57%	1	25.00%	1	8.33%

$\chi 2 = 14.875$, df = 12, p = 0.248

There was no significant difference in Results Distribution with respect to Frykman/AO Type among subjects.

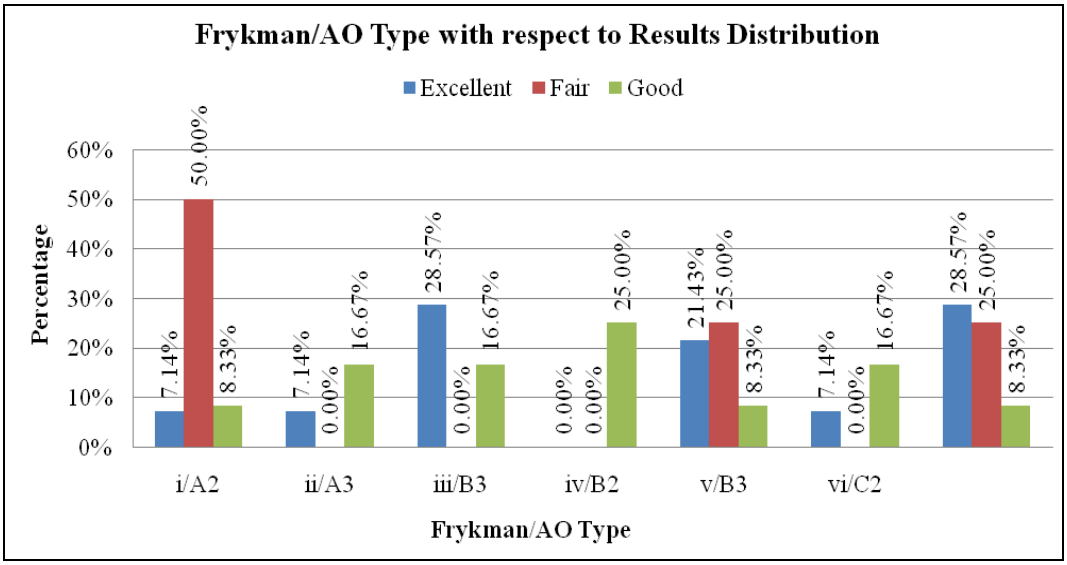

Fig 15: Bar Diagram Showing Frykman/AO Type with respect to Results Distribution among subjects

Summary

Improvements in fixation of materials have provided excellent opportunities for the management of distal radius fractures. The present study was carried out to evaluate functional outcome of lower end radius fractures treated with surgical management with LCP followed by early mobilization of wrist joint.

Most of the patients were males (57%). The commonest age was between 41 to 50 years (30%) and mean age was 42.3 ± 15.18 years. Right sided fracture was noted in 47% of the patients and nature of trauma as RTA was noted in 67% of the patients. Complications of arthritis were present in 3.33% of the patients at third follow up and EPL tendon irritation in 3.33% at second follow up. Maximum patients complained regarding pain during first follow up (60%) while at second and third follow up, the same was noted in 25% and 10% respectively. Swelling was present in 60% of the patients at first follow up which was present in 20% and 5% of the patients during second and third follow up respectively. Clinical union was noted among 85% of the patients and radiological union was noted among 65% at second follow up and in the remaining (35%), it was seen during third follow up. During third follow up, most of the patients had GARTLAND & WERLEY score of 7 or less (85%) with mean scores of 4.67 ± 3.43. The final outcome was excellent in 35% of the patients and good outcome was noted in 50%. No statistically significant association was noted between outcome and mode of injury, side of fracture & type of fracture.

Based on the findings of this study it may be concluded that, locking plate fixation for distal radius fractures provided favourable outcome in patients requiring operative intervention with early mobilization of wrist joint.

Conclusion

- Distal end radius fractures are a very common entity encountered by orthopaedicians worldwide in the emergency department. Although these fractures have been studied extensively for over 200 years now, there is still no treatment free of complications.
- The present study demonstrates good to excellent results in the majority of patients based on G&W functional outcome evaluation after locking plate fixation of the lower end distal radius with lower rate of complications.
- Hence locking plate fixation may be recommended for distal radius fractures
- Requiring operative intervention with early mobilization of wrist joint.

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