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Intra-articular distal radius fractures treated with variable angle locking compression plates: An outcome analysis

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Abstract
Background: Methods for surgical fixation of intra-articular distal end radius fractures has been on an evolving course. One among the novel developments is the use of variable angle locking plate. Its multidirectional locking option facilitates fixation of even the most complex of the fractures, especially in osteoporotic bone.
Aim: To study the functional and radiological outcome of operative management of intra-articular fractures of distal end of radius with variable angle locking compression plates.
Material & Methods: 56 adult patients (36 males and 20 females) who had intra-articular distal radius fractures satisfying the study criteria & treated at Sunshine hospitals, Secunderabad, Telangana, India between October 2015 and September 2017 using variable angle locking compression plates were taken up for the study. The cases were followed up at 6 weeks, 3 months, 6months and 12 months postoperatively. During each visit, functional outcome was assessed using Demerit score system of Gartland and Werley. Radial height, radial angulation and palmar angulation were measured from the xray to assess the radiological outcomes.
Results: There were 2 type B1, 8 type B2, 16 type B3, 13 type C1, 12 type C2 and 5 type C3 as per the AO classification. Functional assessment showed 29(51.78%) excellent results, 21(37.5%) good results, 6(10.71%) fair results and no poor results There was no significant difference in the radiological parameters between different follow-ups as signified by p value >0.05 implying that there was no loss of fixation. One patient had flexor pollicis longus tendon rupture at 13 months postop & was managed by Plate removal + transfer of Flexor Digitorum Superficialis tendon. Two patients developed superficial wound infection which susbsided with oral antibiotics. One patient developed Reflex Sympathetic Dystrophy which was managed medically. One patient had Screw malpositioning but remained asymptomatic through out the follow up period.
Conclusion: Variable angle locking plate offers predictable and good outcome in intra-articular fractures of the distal end of the radius.

Keywords: Variable angle locking plate, distal radius fracture, VA plate

Introduction
Intra-articualar fractures of distal end of radius continue to pose a therapeutic challenge. Malunion can lead to various complications like post traumatic osteoarthritis, decreased grip strength and endurance, as well as limited motion and carpal instability [1].
Open reduction and internal fixation is indicated to address the unstable distal radius fractures and those with articular incongruity that cannot be anatomically reduced and maintained through external manipulation and ligamentotaxis, provided sufficient bone stock is present to permit early range of motion [2].
Internal fixation of metaphyseal bending fractures has become increasingly popular due primarily (a) to directly control and maintain physiologic palmar tilt, (b) to prevent collapse with external fixation, and (c) to avoid bridging the radiocarpal joint. Volar plating is preferred, as the screws directly buttress against collapse and loss of palmar tilt. With smaller and more distal fragments, a dorsal plate has to be positioned distally on the dorsum of the radius making extensor tendon injury more likely [3].
With fixed angle locking plates, the locking screws support subchondral bone and resist axial forces. Compression of locking compression plate to bone is unnecessary and preserves periosteal blood supply [4].

Fixed angle construct can provide additional strength to fixation by constructing a scaffold under the distal radial articular surface [5].

Primary stability achieved with locking screw in a plate prevents secondary displacement irrespective of the bone enabling good results in osteoporotic bones and young patients [6].

Most modular fixed angle volar locking plates have a predetermined volar tilt and radial inclination designed into the plate. Thus, the direction of the distal locking screw is guided by plate design.

However, while the predetermined volar tilt and fixed direction of distal locking screws can restore volar tilt in most fractures, difficulty arises in case of comminuted fractures, when a surgeon himself needs to fine tune the fixation with the aid of additional k wires or use of dorsal plates. The purpose of this study is to evaluate functional and radiological outcome in patients with intraarticular distal radius fractures treated with a volar variable angle locking compression plate.

Material and Methods

This Prospective study was done on 56 patients operated in Department of Orthopaedics, Sunshine hospital, Secunderabad, Telangana between October 2014 and September 2016. Institutional Ethics Committee approval was obtained for the study and patients' consent was taken using patient information sheet and informed consent form.

Inclusion criteria

- Adults (aged over 18years)
- AO fracture classification Type B and Type C

Exclusion criteria

1. Delayed presentation (> two weeks)
2. Compound fractures
3. Pathological fractures
4. Previous ipsilateral distal radius fracture
5. Other fractures of the ipsilateral radius
6. Associated injuries that prevent compliance with subsequent rehabilitation protocols (i.e., severe head injuries, spinal cord injury).
7. Associated carpal bone fractures and neurovascular injuries

Following admission to the hospital,after careful history taking and clinical examination involved forearm was immobilized in a below elbow POP slab and kept elevated. Pain and inflammation was managed using analgesics and anti-inflammatory drugs.

Standard posteroanterior and lateral radiographs were taken and fracture pattern was analysed and categorised according to the AO Classification by a Senior Hand Surgeon. After relevant preoperative investigations, preanaesthetic checkup and informed written consent the patients were taken for surgery. Regional our general anaesthesia was used and ORIF was performed using Modified Henry's approach using a 2.4mm variable-angle volar locking plate under fluoroscopy guidance. Operated limb was immobilised using a below elbow slab.

Fig 1: Clover-leaf locking threads of the variable-angle plate

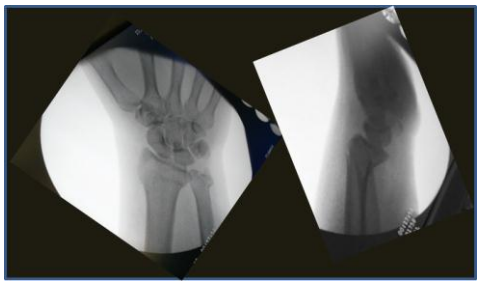


Fig 2: Initial closed reduction under image intensifier

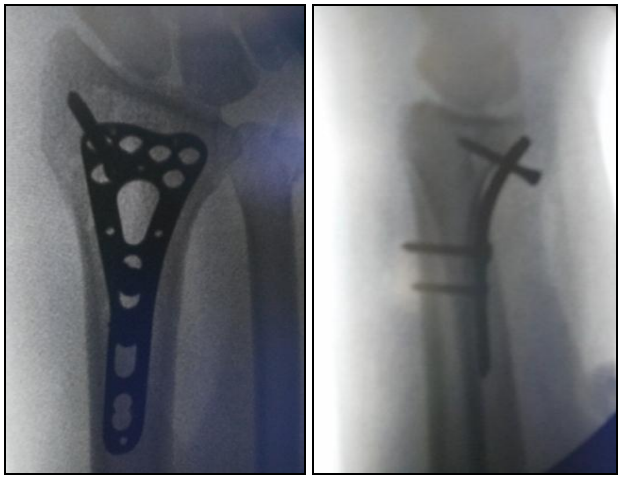


Fig 3: Reduction with plate and capture of radial styloid fragment

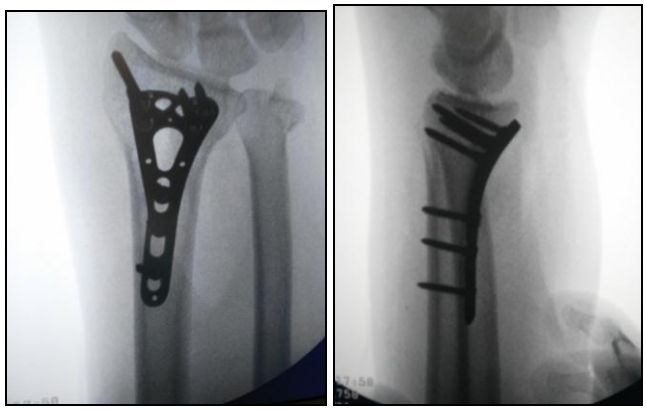


Fig 4: Final fluroscopy image with corrected radiological parameters

Postoperative check X-rays are taken in both postero-anterior & lateral views. The radial height, radial angulation and palmar angulation were measured from the xray and documented.

Patient was encouraged to do active finger and elbow movements and below elbow slab was continued until suture removal at 2 weeks post surgery. Wrist physiotherapy was started at 2 weeks and all cases were followed up at time periods of 6 weeks, 3 months, 6months and 12 months post-operatively.

At each follow up, a check X-ray was taken and functional assessment was done.

Radiological assessment is done based on following parameters

1. The radial angulation (or inclination), measured on AP view represents the angle between one line connecting the radial styloid tip and the ulnar aspect of the distal radius and a second line perpendicular to the longitudinal axis of the radius. The radial inclination ranges between 21 and 25 degrees.
2. The palmar tilt (or palmar slope) is measured on the lateral radiograph as the angle created between the articular surface of the distal radius and a line perpendicular to the longitudnal axis of the radius and is between 0-12^0)
3. The radial height measured on the AP radiograph, relates the length of the radius to the ulna by the distance between 2 perpendicular lines to the long axis of the radius, one joining the tip of the radial styloid process and the other, the surface of the ulnar head. Normally the radial length averages 11-12 mm.
4. Functional outcome was assessed using using Demerit score system of Gartland and Werley. Flexion, Extension, supination, pronation, radial deviation and ulnar deviation of wrist were measured. The grip strength was measured in kilograms and as a percentage of the normal strength of the other wrist.

Statistical analysis

Continuous variables in different groups presented with mean values were compared using paired t-test with statistical difference defined as 5% ($P \leq 0.05$). All statistical analysis was performed using IBM SPSS Statistics for Windows ver. 24.0 (IBM Corp., Armonk, NY, USA).

Results

Table 1: Patients' clinical profile

Age	**45.2+/-12.6 years**
Gender	
Male	**32**
Female	**24**
Side affected	
Right (Dominant side)	**26**
Left (Non-dominant side)	**30**
Mode of injury	
Road Traffic Accident	**36**
Accidental fall	**20**
Type of fractue(AO fracture classification)	
23-B1	2
23-B2	8
23-B3	16
23-C1	13
23-C2	12
23-C3	5
Total	56

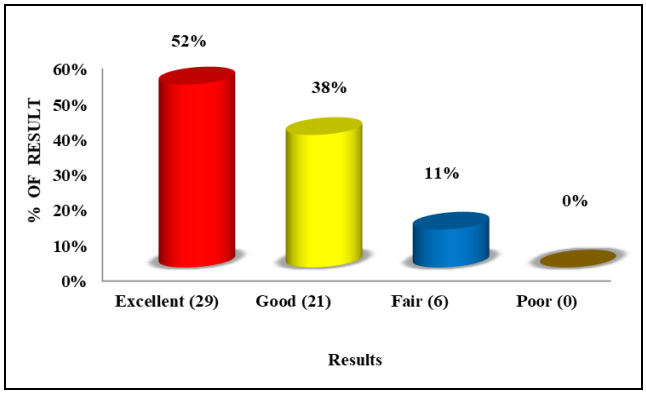
Surgery was done between 1-5 days in 50 (90%) patients as an elective procedure. Surgery was done between 6-10days in 6 (10%) because of reasons like late presentation, waiting of anaesthesia fittness etc.

Table 2: Comparing radiological parameters

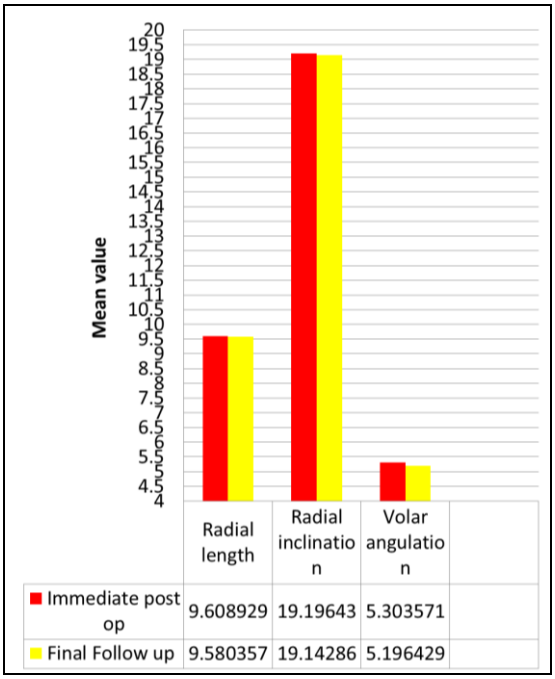
Parameter	**Immediate postop**	**One year postop**	**p value**
Radial angulation	19.19643±2.467587	19.14286±2.452669	0.083213
Volar tilt	5.303571 ±2.441457	5.196429±2.766157	0.159161
Radial length	9.4608929±1.669434	9.580357±1.722727	0.065943

Table 3: Summary of the Demerit scoring system of Gartland and Werley

Follow up visit	**Score**
1.5 months	10.75+/-4.069
3 months	6.07+/-3.97
6 months	3.38+/-3.52
12 months	3.12+/-3.223



Graph 1: Showing Results (According to Gartland and Werley Demerit Scoring System)



Graph 2: Radiological Outcome

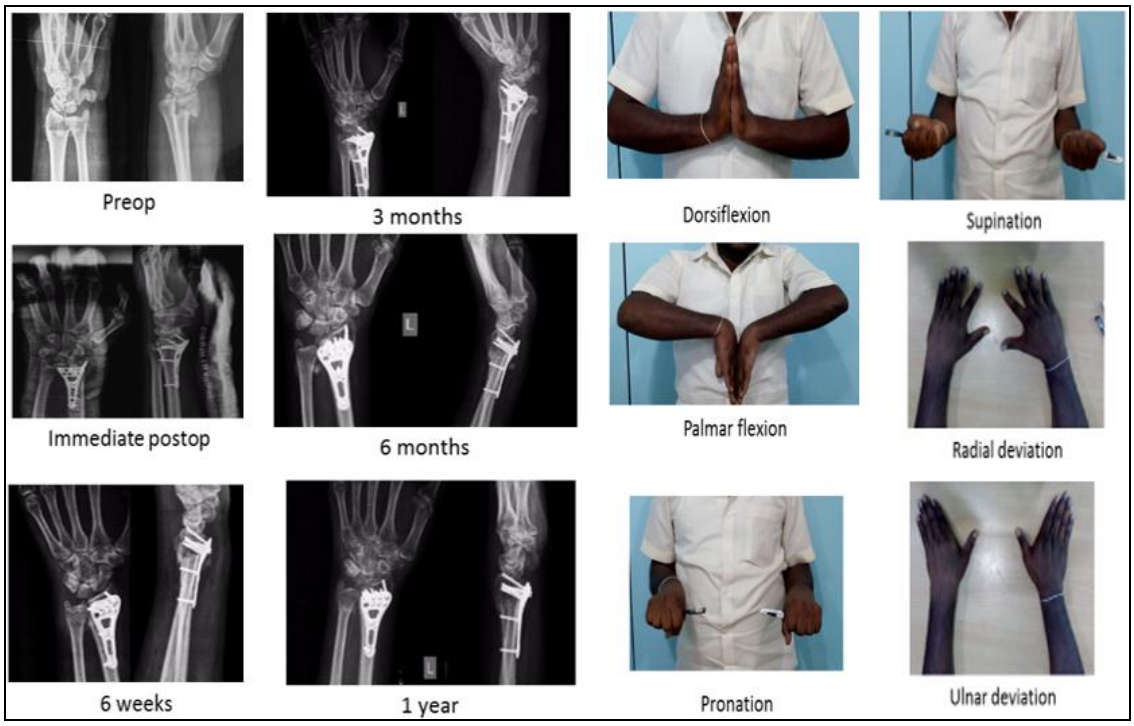


Fig 5A: (Left) – Anteroposterior and Lateral radiographs of a patient operated using variable angle locking plate. 5B (Right) – Clinical images of the same patient at 6 weeks followup showing early return of functional range of movements

Complications

One patient had flexor pollicis longus tendon rupture because of tendon irritation & was managed by Plate removal + transfer of Flexor Digitorum Superficialis tendon to Flexor Pollicis Longus at 13 months postop. Two patients developed superficial infection which susbsided on giving antibiotics for 10 days. One patient developed Reflex Sympathetic Dystrophy(RSD),was managed medically and recovered. One patient had Screw malpositioning but remained asymptomatic through out the follow up period.

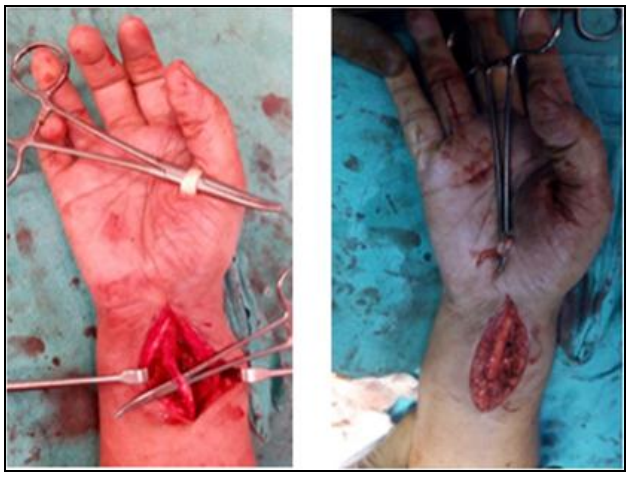


Fig 6: flexor pollicis longus tendon rupture managed by Plate removal + transfer of Flexor Digitorum Superficialis tendon to distal end of Flexor Pollicis Longus

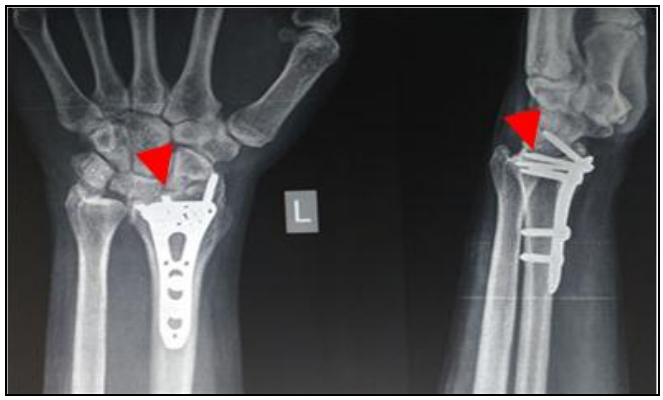


Fig 7: Screw malpositioning

Discussion

Intra-articular distal end radius fractures demand an anatomical reduction of articulate surface and restoration of radiological parameters for a good functional outcome.[7] External fixation could not effectively protect comminuted distal radial fractures from loss of reduction, which showed no correction of volar tilt and gradual loss of radial height and radical inclination causing shortening and redisplacement [8]. Volar plate fixation with fixed-angle locking screws for the unstable distal radius fractures has shown acceptable functional and radiographic parameters [9, 10]. At the same time, some studies on use of fixed angle plates have shown loss of reduction on short term follow up [11, 12]. Variable angle plates were introduced to address these concerns. Stanbury *et al*. conducted biomechanical analysis of a volar variable-angle plate which showed excellent resistance to articular stepoff at load to failure and were similar to volar fixed angle plates in terms of the mean load to failure on cyclical loading. They highlighted that variable-angle fixation exhibited a distinct mechanical advantage over fixed- angle plates in the setting of a smaller radial styloid fragment due to fragment-specific fixation allowed by customized screw placement.[13] The use of variable-angle locking screws allows increased flexibility in plate positioning to accommodate various fracture lines(proximal/distal and medial/lateral) [14]. Khatri *et al* and Fowler *et al*. and Marlow *et al*. found no cases of significant loss of radiological parameters in the follow-up period following fixation [15-17] In our study also, on comparison of radiological parameters at immediate postop and 1 year follow up, no significant difference was noted(p value <0.05) indicating no significant loss of reduction.

Asadollahi *et al*. in their systemic review pointed out that placement of volar plates placed distal to watershed line to fix articular fragments could result in late flexor tendon ruptue.[18] We had one case of late rupture of flexor policis longus tendon at 13 months which was found to be due to misplacement of plate distal to the watershed line. The case was managed by removal of plate and transfer of Flexor Digitorum Superficialis (FDS) tendon of ring finger to Flexor policis longus tendon in the hand.

Benson LS *et al*. reported the use of additional fixation methods like K wires or dorsal plates in comminuted fractures (mostly AO type C3) [19]. This can be minimised by using screws which can be directed specifically to capture various fragments as in our study were we could fix the fracture using a single variable angle volar plate in all our cases.

At the same time, if not done under proper fluoroscopic guidance, this adaptation of screw direction can result in screw malpositioning. Our study had one case of screw malpostioning who remained asymptomatic through out the study period. This was also reported by Khatri *et al* in one patient who remained asymptomatic during follow up period [15] and T singh *et al* in one who subsequently developed post-operative carpal tunnel syndrome after the screw was removed [20]. Pace A *et al*. has advices the use of different articular wrist views to assess and avoid the risk of intra-articular screw penetration [21].

Table 4: Sex distribution

Series	Males	Females
Khatri K *et al*.[15]	18	5
Fowler *et al*.[16]	11	26
Marlow *et al*.[17]	51	14
T.singh *et al*.[20]	10	20
Present study	36	20

Increased incidence in males in most of the studies is probably due to their involvement in outdoor activities, riding vehicles and heavy manual labour.

Table 5: Involved side

Series	Dominant side	Non-dominant side
Khatri K *et al*. [15]	17	6
Fowler *et al*. [16]	21	16
Marlow *et al*. [17]	16	49
Present study	26	30

Table 6: AO fracture type

Series	AO fracture type (%)								
	A1	A2	A3	B1	B2	B3	C1	C2	C3
Khatri K *et al*. [15]	-	-	4	-	-	-	-	9	10
Fowler *et al*. [16]	5			2			30		
Marlow *et al*. [17]	15			5			45		
Present study	-	-	-	2	8	16	13	12	5

4. Complications

We encountered a complication rate of 8.9 % out of which 1 had Flexor Pollicis Longus tendon rupture, one had Reflex Sympathetic Dystrophy, two had Superficial infection and one had Screw malpositioning.

Table 7: Complications

Series	Complication rate
Khatri K *et al*. [15]	21.74%
Fowler *et al*. [16]	5.4%
Marlow *et al*. [17]	7.69%
Present study	8.9%

Reports of Flexor pollicis longus (FPL) rupture after volar plate fixation were given by Valbuena *et al*, Cognet *et al* and Bell *et al*. [22-24] They mentioned placement of plate distal to watershed line or it becoming so as a result of collapse of fracture and prominence of distal edge of the plate or the screw heads as possible causes of tendon rupture. Valbuena *et al*. recommends early plate removal in the above mentioned conditions. [22] Kawasaki *et al*. recommends the use of a low profile contoured plate to minimize this complication [25].

In our case patient presented with loss of flexion of interphalangeal joint of right thumb at 13 months. The plate was seen positioned distal to the watershed line. FPL rupture was suspected and intra-op complete FPL rupture was seen with retraction of the distal end of tendon into the arm and proximal end was seen fibrosed and attached to surrounding soft tissues. ue to larger defect, Fracture had healed completely. Defect was large and hence grafting was not attempted and Flexor Digitorum Superficialis (FDS) tendon of index finger was mobilised and sutured to the FPL tendon the hand using Pulvertaft technique. Postop the limb was splinted and mobilization was started after 3 weeks and recovery was good.

R Mehrzad *et al*. compared the complication rates between Variable angle and fixed angle distal radius plates and they noted 11 complications in the fixed angle group out of which 7 were hardware related while no hardware relaed complications were noted in variable angle group [26].

Screw malpositioning was also reported by Khatri *et al* (2015) in one patient who remained asymptomatic during follow up period[15] and by T singh *et al*. (2010) in one who subsequently developed post-operative carpal tunnel syndrome after the

screw was removed [20] Pace A *et al*. advices the use of different articular wrist views to assess and avoid the risk of intra-articular screw penetration [21].

Our study had 2 cases of superficial infections managed by oral antibiotics for 10 days and regular change of dressings. Khatri *et al*. has also reported about 2 cases with superficial infection managed by oral antibiotics [15] Reflex sympathetic dystrophy / complex regional pain syndrome (CRPS) was noted in one patient in our study who didn't follow the physiotherapy protocol and continued using a wrist splint for 2 months postop. He was managed by monitored gentle physiotherapy, and medications like GABA agonists and he recovered in 1.5 months.

Marlow *et al*. reports about two patients who presented with complex regional pain syndrome (CRPS), both of whom underwent removal of metalwork and their symptoms resolved with a course of physiotherapy [17].

Carpal tunnel syndrome was discussed as a complication in studies by Khatri *et al*, Marlow *et al*. and T singh *et al*. [15, 17, 20] which was not noted in our study. None of our pateints developed wrist arthtitis, screw loosening and back out or extensor tenosynovitis as described by Fowler *et al*. [16]. Bone grafting was not done in any of the cases.

5. Results

In our series, we had 29 excellent,21 good,6 fair and no poor results as per Gartland & Werley demerit scoring system.

Patients, who obtained excellent results, had no residual deformities or pain. Range of motion was within the normal functional range. They had no complications. They were operated within 4 days after injury. Radial length, volar tilt and articular step-off were within normal limits. In the present study ,we could notice that most of the patients who showed excellent outcome in final follow up were able to achieve the same or good outcome by as early as 3 months post surgery as they were mobilised early and they have correctly followed physiotherapy protocols. These patients were able to return to their day to day activities early.

Khatri *et al*. also used Gartland & Werley demerit scoring system and had 65.2% excellent, 35% good and no fair or poor results and reported no significant difference in radiological parameters at immediate postop and one year follow up.But in their study the mean follow up duration was 11.04± 2.47months (range 6 to 15) and sample size was less.[15]

In Fowler *et al*. study, there was no statistical difference between first postoperative and 1-year follow-up radiographs for any of the measured variables. Average Disabilities of the Arm, Shoulder, and Hand score was 6 and average visual analog scale pain score was 0.3 signifying excellent clinical outcomes at 1-year follow-up. [16] Marlow *et al*. used Quick DASH, Mayo wrist score and VAS for assessing functional outcomes and compared mean values of radiological parameters at immediate postop and final follow up to compare radiological outcomes which were found to be not statistically significant. (p<0.05). They also compared the results with outcomes of fixed angle plate and found it to be statistically nonsignificant [17].

Sachin *et al* studied the correlation between radiological and functional outcome of post operative intra articular distal end radius fractures by following up the patients for six months. They found that the radiological parameters have an effect on functional outcome The more number of radiological parameters affected poorer is the functional outcome [27].

But Xavier *et al*, (2011) compared the objective and subjective (DASH scores) clinical results from surgical treatment of fractures of the distal radius with radiographic indexes. According to them there is little correlation between these results. They quoted that radial shortening was the only radiographic value to change the patients' objective clinical results and it could influenced the range of motion and grip strength [28].

In our study we couldn't get any appreciable change in the radiological parameters measured at immediate postop and at 1 year postop as signified by p value >0.05. Even though the radiological parameters achieved post surgery was maintained at one year postop in majority of the patients, their functional outcomes were not uniform as signified by distribution of functional outcome into both excellent and good categories pointing to a lack of direct correlation between radiological and functional results.

But we could observe that the patients who had comparatively small postopertive radial length had only fair functional outcome implying a possible correlation between radial length and functional outcome, which needs further evaluation.

5. Limitations of the study: The present study is a prospective noncomparitive study; a Randomised Control study with a control population treated with fixed-angle volar LCPs would have given comparative analysis. The surgeries were done by a surgical team of 3 surgeons; a single surgeon study would have been optimal.

6. Conclusion

The multidirectional screw placement option allows allows subchondral placement of screw into regions with solid bone support allowing enhanced intra-fragmentary fixation in complex comminuted fracture patterns. It is a valid option in treatment of comminuted intra-articular fractures (like AO 23 C1-C3 types) and in many cases avoids the need for additional fixations like k wires,screws or mini-fragment plates and also brings down surgical time and fluoroscopy exposure.

Even though many studies showed comparable functional results between fixed and variable angle designs in late postoperative period, sustained retention of the intraoperative reduction and less incidence of loss of reduction shown by this system allows for early postoperative mobilization and early return to day to day activities as evidenced by the better functional scores during initial follow ups.

In conclusion, variable volar locking plates allows early mobilisation without the fear of loss of reduction and fracture collapse and hence can yield good functional results. It is a treatment method with low complication rate and could thus be a useful modality for managing unstable distal end radial fractures facilitating early rehabilitation and recovery.

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