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ORIGINAL ARTICLE

A PROSPECTIVE COMPARATIVE STUDY OF THE LIMITED CONTACT DYNAMIC COMPRESSION PLATE WITH THE DYNAMIC COMPRESSION PLATE FOR DIAPHYSEAL FRACTURES OF THE HUMERUS

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ABSTRACT: BACKGROUND: Diaphyseal fracture of the Humerus is a common fracture in the upper limb. Various treatment modalities like P.O.P, Plate and nail are used in the treatment. Limited Contact Dynamic compression plate has been promoted by some as a better plate than the Dynamic Compression Plate. The aim of our study is to find the difference between the mean duration of union between the DCP and the LCDCP in diaphyseal fractures of the Humerus and to find the difference in the functional outcome as measured by the DASH questionnaire. **MATERIALS AND METHODS:** From October 2004 and December 2005, thirty patients with Diaphyseal fractures of the humerus were treated with compression plating by compression plating using Dynamic Compression Plate or Limited Contact Dynamic Compression Plate. The time taken for radiological union in the two groups was noted and the difference in the time between the two groups was calculated. After radiological union occurred, the functional outcome was assessed by the Disabilities of Hand, Shoulder and Elbow (DASH) Questionnaire. **RESULTS:** There was no statistically significant difference in the two groups with respect to age, sex, mode of injury, side of injury and AO type. The average time taken for union in the DCP group was 16.53 weeks and in the LCDCP group it was 15.86 groups. The average time for union in all the thirty patients was 16.2 weeks. The functional outcome was excellent in 17 patients (8 in the DCP group and 9 in the LCDCP group) and good in 13 patients (7 in the DCP group and 6 in the LCDCP group). **CONCLUSION:** Since we found no statistically significant difference in the time taken for union and the functional outcome between the two groups, we conclude that the theoretical advantage of the LCDCP does not translate into clinical advantage when used in Diaphyseal fractures of the humerus.

KEYWORDS: Humerus, Diaphyseal humerus Fracture, Fracture, Dynamic compression plate, Limited contact dynamic compression plate, DASH questionnaire.

INTRODUCTION: Fractures of the diaphysis of the Humerus and its complications are a major cause of morbidity in trauma patients in this region and globally. Any fracture causes untold misery to the patient in terms of pain, psychological trauma, loss of function and economic loss.

Fractures of the humeral shaft account for 20 % of the humeral fractures[1] and about 3-5 % of all fractures.[2] This is becoming more common because traffic accidents are on the rise and rescue teams have become more efficient in enabling the polytrauma patient to survive till he reaches the hospital. Humeral fractures have a bimodal pattern in terms of age and sex of patients. The 1st peak is seen predominantly in young males in the age group 21-30 years which occurs due to high energy trauma.[2] The 2nd peak in seen in females of age 60-80 years which are usually due to simple falls.[2]

Humeral shaft fractures usually occur due to direct trauma, although indirect trauma may also be the cause.[3] Direct trauma may be due to road traffic accidents, fall, direct blow on the arm.

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This usually causes a transverse or comminuted fracture. Indirect violence include fall on outstretched hand, twisting injuries and violent muscular contraction. These usually cause a spiral or oblique fracture. Fractures of the shaft of the humerus resulting from muscular violence are uncommon. However such fractures have been reported following arm wrestling and throwing of baseball and hand grenades. These fractures usually are located between the middle and distal third of the humerus.[4,5,6,7]

The goals of treatment of humeral shaft fractures are to achieve acceptable alignment and to restore patients to their prior level of function. This can be achieved by non-operative and operative means.

Non Operative: The humeral shaft is well enveloped by muscle and has robust blood supply. The wide range of motion of the shoulder and the elbow allows for accommodation of certain degrees of angular, axial and rotational malunion.[2] Sir John Charnley has said "humerus is perhaps the easiest of the major long bones to treat by conservative methods."[2] Because of the aforementioned facts, closed treatment is the initial treatment of choice for most humeral shaft fractures. A union rate of 90 – 100% can be expected.[8]

The various treatment modalities can be broadly divided into two Groups.

1. Dependency traction methods.
2. Thoraco brachial immobilization.

Dependency Traction: Here gravity reduces the fracture and maintains the reduction as long as the arm is dependent.

1. Hanging arm cast.
2. Coaptation splint or 'U' slab.
3. Functional cast bracing.
4. Skeletal traction.

The types of Thoraco brachial immobilization are:

1. Jacksonville sling[8] or Stockinette Velpeau shoulder dressing[9].
2. Sling and swathe.
3. Open Velpeau type cast.
4. Shoulder spica.

Though majority of the simple fracture are managed non operatively, specific indications exist for operative treatment.[2] The indications can be divided into fracture indications, associated injuries, and patient indications.

1. **Fracture Indications:**
   a) Failure to obtain and maintain adequate closed reduction.
      - Shortening greater than 3 centimeter.
      - Rotation greater than 30 degrees.
      - Angulation greater than 20 degrees.

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b) Segmental fractures.
c) Pathologic fractures.
d) Intraarticular extension.
   - Shoulder joint
   - Elbow joint.

2. Associated Injuries:

a) Open wound.
b) Vascular injury.
c) Brachial plexus injury.
d) Ipsilateral forearm fractures.
e) Bilateral humeral fractures.
f) Lower extremity fractures requiring upper extremity weight bearing.
g) Burns.
h) High velocity gunshot injury.
i) Chronic associated joint stiffness of shoulder or elbow.

3. Patient Indications:

a) Polytrauma.
b) Head injury (Glasgow coma scale lesser than 8).
c) Chest trauma.
d) Poor patient tolerance.
e) Unfavorable body habitus.
   - Morbid obesity.
   - Large breasts.
f) Parkinson's disease and other neurological diseases.[3]

Closed reduction is the mainstay of treatment of Diaphyseal fractures of the humerus[3]. Operative treatment is required only if indicated[2]. Operative treatment commonly involves either plating or intramedullary nailing. The Dynamic compression plate (DCP) is commonly used for this purpose. The Limited contact dynamic compression plating (LC-DCP) was developed in the mid 1980's on the premise that Dynamic compression plate caused damage to the cortical blood supply of the bone due to its greater bone-plate interface.[10,11]

We have undertaken this study to see if the theoretical advantage of the LC-DCP can be translated into clinical advantage in terms of time taken for union and functional outcome.

In 1969, Allgower and Perren reported the 'dynamic compression plate' (DCP) as a method for providing rigid internal fixation. This was a revolution in treatment of Diaphyseal fractures. Good results after plating became the rule rather than the exception.

A multicenter study was conducted in America from 1970 to 1983. Ninety six patients with fresh fracture or nonunion were included in the study. Twenty seven patients were treated with AO plating methods and there was union in 100 percent of the cases with good functional outcome.[12] From 1976 to 1983, thirty nine humeral shaft fractures were plated in patients with multiple injuries at the sunny brook medical center Toronto. Thirty four came for follow up and out of these only one

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developed non-union.[13] Eighteen patients with humeral shaft fractures underwent open reduction and internal fixation (ORIF) using the AO plating technique at the Kantonsspital Chur in Germany from 1980 to 1986. The overall result was excellent in 9 patients, good in 5 patients, fair in 2 patients and poor in one patient with complete brachial plexus injury. Bone healing was uneventful in all 17 patients.[14]

In the university of Mississippi medical center, Jackson, thirty six patients with Diaphyseal fractures of the humerus were treated with AO plating techniques. Two were lost to follow up. Out of the remaining thirty four patients thirty three showed union. Good functional outcome was seen in all but six patients. The authors concluded that even though closed treatment was the mainstay of treatment of fracture of the shaft of the humerus, internal fixation with proper technique will give acceptable results even in the difficult fractures.[15] In a study in the University of Bonn, plating was used in the treatment of humeral shaft fractures in 62 patients between 1990 and 1994. The average time taken for bony union was 16.2 weeks.[16]

In Singapore between 1992 and 1997, 47 humeral shaft fractures were treated by open reduction and internal fixation with DCP using AO principles. There were two cases of non-union. Both were open fractures. The average time to bony union was 5.3 months. Twenty-six patients had full range of motion of both their shoulder and elbows. Seven patients had residual elbow stiffness. Two patients had reduced shoulder abduction. Eighty nine percent were satisfied or very satisfied with their surgical outcome.[17]

A study was conducted in Paris where the authors treated 104 diaphyseal humeral fractures, 28 of whom were treated with plates and screws. The plate and screws group showed union in 26 cases and very good results in 23 cases and good results in 3 cases[18]. In a study of 156 humeral shaft fractures in adults treated by plate fixation between1987 and 1997 in Marseilles, France, there were 21 cases of multiple trauma and 24 multiple fractures, 8 cases of floating elbow and open fracture in 16. The union rate was 94.2%, sepsis rate was 1.5%. Good or very good outcome was achieved in 86.6% of the cases. Postoperative radial nerve paralysis occurred in 8 cases (5.1%), only one patient suffered persistent severe sequelae. There were also 8 non unions and 3 delayed unions.[19]

In the mid 1980's the Limited Contact Dynamic compression plate was introduced[10,11] with the following theoretical advantages:

1) Minimal surgical damage to the blood supply.
2) Maintenance of optimal bone structure near the implant.
3) Improved healing in the critical zone in contact with the plate.
4) Minimal damage to the bone lining at plate removal with reduced risk of refracture.
5) Optimal tissue tolerance of the implant by selection of pure titanium as implant material.

A cadaveric study conducted in the University of Toronto indicated that Limited contact dynamic compression plate has lesser contact with the humerus.[20]

LC-DCP plates were used to treat upper limb fractures in a series of one hundred and fourteen patients in Boston from 1990 to 1993. Seventeen patients had humerus shaft fracture. Sixteen of the seventeen humeral fractures united in an average of 10.5 weeks. In the whole series, one hundred and eight of one hundred and eleven fractures united without any further problems.[21] Fifty one fractures of the humerus treated with LCDCP in Haryana from 1996 to 1998. Forty eight of the Fifty one fractures united after median ten (8– 13) weeks.[22]

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Titanium LCDCP was used in the treatment of 50 humeral shaft fractures in the Government medical college, Amritsar. The time taken for radiological union was < 16 weeks in more than 96% of the cases and the functional outcome was good to excellent in more than 96% of the cases.[23] In a retrospective study, the low-contact dynamic compression plate (LCDCP) was compared with the internal plate fixator with locked screws for patients with delayed or non-union of the humeral diaphysis, in Hamburg, Germany. There were thirty three patients, fourteen in the LC-DCP group and nineteen in the internal plate fixator group. All patients went on to good union with good functional recovery.[24]

Surgeons in Brazil used the DCP and LC-DCP plates as bridging plates for treatment of humeral fractures in fifteen patients and achieved good results in fourteen.[25,26]

A study conducted in the Sunnybrook health center Canada concluded that variables other than bone plate design like Screw torque, object radius of curvature, mode of bone plate application (compression or neutral loading) also influence the interface contact area and average force between a bone plate and object to which it is applied.[27]

MATERIALS AND METHODS: This study was conducted in the Department of Orthopaedics at K.L.E.S Hospital and Medical Research Center, Belgaum and District Hospital Belgaum between October 2004 and March 2007.

During this period thirty patients with Diaphyseal fractures of the humerus with indications for surgical management were included in the study.

INCLUSION CRITERIA:

1. All closed Diaphyseal fractures of Humerus with an indication for surgical management.
2. Age group above 18 years.

EXCLUSION CRITERIA:

1. Open Fractures.
2. Pathological Fractures.
3. Age group below 17 years.

The patients who met the inclusion and exclusion criteria were included in the study after taking informed consent. A thorough history and clinical examination was done. The presence or absence of radial nerve injury was recorded. Roentgenogram of the arm with shoulder and elbow was taken in both antero-posterior and lateral views. Additional roentgenograms were taken if any other injury was suspected. The humeral shaft fracture was temporarily immobilized with a U-slab and sling.

The patients were then randomized by a computer generated list into two groups. In the first group, 4.5 mm narrow stainless steel LCDCP was used and in the second group, 4.5 mm narrow DCP was used. Thirty patients were included in the study, fifteen each in the LCDCP and DCP groups.

Once the patient was randomized, Pre-operative planning and investigations were done and the patients were treated with DCP or LCDCP. After the surgery, the arm was immobilized with a U slab till the pain decreased and then movements of the shoulder and elbow were started. In cases of poor bone quality or comminuted fractures the slab was continued for three weeks.

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The patients were followed up every second week till radiological union was seen. At every follow up clinical examination was done to assess status of the surgical wound, pain, tenderness, range of motion of shoulder and elbow, stability of the fracture and clinical union. Roentgenograms were taken in AP and Lateral views to look for signs of radiological union. In our study clinically, union was said to have occurred when the fracture site has become stable and pain free. Radiologically, union is said to have occurred when plain X-Ray shows bone trabaculae or cortical bone crossing fracture site on at least three surfaces on orthogonal radiograms.

The time taken for clinical and radiological union to occur was noted. Delayed union was said to be present if after sixteen weeks, no clinical signs of union are seen. Non-union in our study was defined as absence of fracture union after thirty two weeks after injury.

The functional outcome was measured by the Disabilities of Arm, Shoulder and Hand (DASH) Questionnaire[28, 29,30] at nine months or at full recovery which ever was earlier. The time taken for clinical and radiological union and the functional outcome in both groups were then compared.

RESULTS: There were 30 patients in our study. 15 patients were treated with DCP and 15 were treated with LCDCP. The age of the patients in the DCP group ranged from 19 to 60 years with a mean age of 38.06 years. The age in the LCDCP group ranged from 18 to 58 years with a mean age of 38.44 years. In the DCP group there were 11 males and 4 females. In the LCDCP group there were 12 males and 3 females. The most common mode of injury overall and in both groups was Road traffic accident (RTA). Assault was the second most common cause. All cases of fracture due to fall were in the elderly patients.

Mode of injury	DCP	LC-DCP	Total
Road traffic accident	11	10	21
Assault	3	2	5
Fall	1	3	4

Table 1: Mode of injury

Left side was the most common side involved in both groups. Both groups were similar with respect to the side of fracture. Fifteen fractures occurred in the middle one third of the diaphysis 8 in the DCP group and 7 in the LCDCP group. The next common site in our study was the lower one third which accounted for 6 patients. Fractures at the junction of the middle one third and lower one third and fractures occurring at the junction of the upper one third and middle one third accounted for 4 patients each.

There were eleven patients who had associated injuries. In the DCP group, two patients had head injury which was managed conservatively, one had a fracture of the tibia and fibula which was treated by closed reduction and internal fixation by interlock nailing, one patient had a comminuted left subtrochanteric fracture which was fixed using a long 95 degree DHS, one patient had a distal end radial fracture in the contra lateral limb and one patient had an ipsilateral brachial artery injury which was repaired and the patient had full functional recovery.

In the LCDCP group, one patient had head injury which was managed conservatively, one had a type 2 open fracture of the tibia which was treated with an external fixator which was removed at 6 weeks and a cast applied, one patient had a supracondylar fracture of the contralateral humerus

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which was treated with open reduction and K-wire fixation, one patient had a fracture of the shaft of the right femur at the isthmus which was fixed with a K nail and one patient had a soft tissue injury of the ipsilateral knee. Three patients had a primary radial nerve injury. The radial nerve was explored in all these cases and found to be intact but contused. All of them went on to complete recovery by 6 months. Post-operative radial nerve palsy was seen in one patient each in the DCP and LCDCP groups. Both recovered full function at 8 months and 2 months respectively. The average delay between injury and surgery was 6.8 days in the DCP group and 7.8 days in the LCDCP group.

The indications for surgery in our series were, failed closed reduction in 17 patients, polytrauma requiring early mobilization of the patient in 6 cases, bilateral Upper limb fracture in 2 patients, primary radial nerve palsy in 3 patients, brachial artery injury in one patient and morbid obesity in one patient. The average duration of follow up in our study was 10.13 months. Range is 6-19 months.

The average time taken for clinical union was 11.33 weeks in the DCP group and 10.66 weeks in the LCDCP group. The difference was 0.66 weeks but this difference was not significant as on the student T test, the t value was 0.703 with P value of 0.487.

Clinical union	DCP	LC-DCP	Total
Minimum	8 weeks	8 weeks	8 weeks
Maximum	20 weeks	14 weeks	20 weeks
Mean	11.33 weeks	10.66 weeks	11 weeks
Standard deviation	3.11	1.95	2.573
Significance	t = 0.703, P value = 0.487		

Table 2: Time taken for clinical union

The average time taken for radiological union was 16.53 weeks in the DCP group and 15.86 weeks in the LCDCP group. There was no significant difference in the time taken for radiological union (P value > 0.05).

Radiological union	DCP	LC-DCP	Total
Minimum	12 weeks	12 weeks	12 weeks
Maximum	28 weeks	20 weeks	28 weeks
Mean	16.53 weeks	15.86 weeks	16.2 weeks
Standard deviation	4.103	2.474	3.346
Significance	t value = 0.538, P value= 0.594		

Table 03: Time taken for radiological union

The average DASH score of the whole series was 13.54 / 100 (Lower the score better the function). The average DASH score in the DCP group was 13.69 and in the LCDCP group it was 13.39. But as the P value was greater than 0.05, There was no statistically significant difference in the DASH score in the two groups.

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	DCP	LC-DCP	Total
Worst	32.5	30.83	32.5
Best	0.83	0.83	0.83
Average	13.69	13.39	13.54
Standard Deviation	11.32	10.44	10.7
Statistical significance	t value = 0.075., P value = 0.94.		

Table 4: Comparison of DASH scores

DASH scores of 0-20 were taken as excellent, 20-40 were taken as good, 40-60 fair and above 60 was taken as poor. There were no fair or poor results in our series. Overall there were 17 excellent and 13 good results. In the DCP group there were 8 excellent and 7 good results. In the LCDCP group there were 9 excellent and 6 good results. Even though the numbers of excellent results are more in LCDCP group, it is not statistically significant. This was calculated by the chi square test. The chi square value came as 0.136 with P value of 0.7125.

Result	DCP	LC-DCP	Total
Excellent	8	9	17
Good	7	6	13
Fair	-	-	-
Poor	-	-	-

Table 5: Comparison of end results

$\chi^2 = 0.136$, P value = 0.7125.

Complications seen were radial nerve palsy, delayed union, pain and decreased range of motion.

	Complication	DCP	LCDCP
1	Radial nerve palsy	1	1
2	Delayed union	1	0
3	Pain and decreased mobility of the shoulder or elbow	2	2

Table 6: Complications

So as has been described both groups were homogenous with respect to sex, age, fracture type, mode of injury and side of injury.

The difference noted in the time for clinical and radiological union between the 2 groups was less than a week each and on statistical analysis there was no significant difference in the time for union. There was no statistically significant difference in the functional outcome in both groups.

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DISCUSSION: Closed reduction and functional cast bracing is the mainstay of treatment of diaphyseal fractures of the humerus.[2,3,9,6,32-38] Specific indications exist for the surgical management of humeral shaft fractures.[2]

Although some authors consider intramedullary nailing as good alternative for plating, compression plating is the gold standard for operative management[32]. In our study, we managed thirty patients with diaphyseal fractures of the humerus by compression plating, using DCP in 15 patients and LCDCP in 15 patients. All cases were plated using 4.5 mm narrow stainless steel DCP or LCDCP. In our study, we used narrow limited contact dynamic compression plates because the Indian patients have a smaller diameter of the humerus when compared to a European population, the edges of a broad plate tending to overhang the humeral cortices. Secondly a broad plate has offset holes, which when used for fixation of a narrow diameter humeral shaft will cause the screws to be nearer the edge of bone rather than in the center.[22]

In the DCP group, all fractures united and the time taken for clinical union and radiological union was 11.33 weeks and 16.53 weeks. The time taken for union in various series of surgical treatment of humeral shaft fracture with DCP ranges from 12.5 weeks to 22.7 weeks.[12.13.15-17,39,40] One of the reasons for this wide difference is that union is defined differently by various authors. In our study, we defined radiological union as bone trabaculae or cortical bone crossing fracture site on at least three surfaces on orthogonal radiograms.

Series	Number of patients	Time for Union	Union Rate
Bell et al[13]	38	19 wks	97%
Seibert et al[28]	62	16.2 wks	-
Hee et al[17]	35	22.7 wks (5.3 Mths)	94.29%
Fang-yao et al[39]	30	12.5 wks	95%
Vander griend et al[15]	36	-	97%
Foster et al[12]	45	-	96%
McCormack et al[40]	23	-	95.45%
Our Series	15	16.53 wks	100%

TABLE 7: Comparison of time for union and union rate of DCP with other series

The time taken for clinical and radiological union in the LCDCP group was 10.66 and 15.86. The time taken for radiological union in other series was 10 weeks to 16 weeks.[22,23]

Series	Number of patients	Time for Union	Union Rate
Gupta et al[27]	51	10 weeks	100%
Chhina et al[28]	50	16 weeks	100%
McKee et al[26]	17	-	100%
Our series	15	15.86 weeks	100%

Table 8: Comparison of time for union and union rate of LC-DCP with other series

The functional outcome was assessed in our study by using the DASH scoring system and then the results were grouped as excellent, good, fair and poor. Overall there were 17 excellent and 13

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good results. In the DCP group there were 8 excellent and 7 good results. In the LCDCP group there were 9 excellent and 6 good results.

The functional outcome of our series also matched the different series we reviewed.

Series	Results			
	Excellent	Good	Fair	Poor
Leutenegger et al[14]	52.9%	29.4%	11.7%	5.9%
Paris et al[19]	53.6%	33%	1.8%	11.6%
Meekers et al[41]	77.5%	17.5%	2.5%	2.5%
Our series	53.3%	46.7%	-	-

Table 9: Comparison of functional outcome of DCP with other series

In the DCP group there were 53 percent excellent results and 47 percent good results. The excellent results in the other series varied from 53 to 77 percent and the good results varied from 17 to 33 percent.

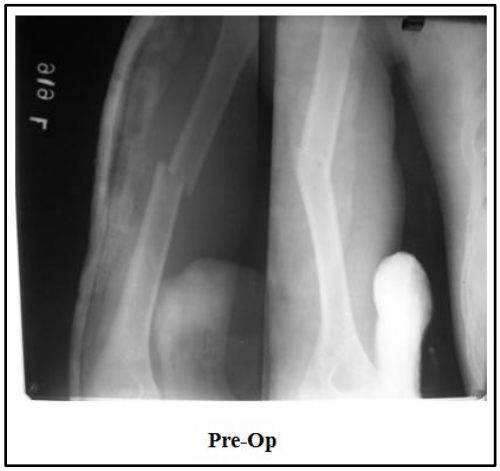
Series	Results			
	Excellent	Good	Fair	Poor
Gupta et al[22]	66.7%	27.4%	5.9%	-
Chhina et al[23]	84%	12%	4%	-
Our Series	60%	40%	-	-

Table 10: Comparison of functional outcome of LC-DCP with other series

In the LCDCP group there were 60 percent excellent results and 40 percent good results. The excellent results in the other series varied from 66 to 84 percent and the good results varied from 12 to 27 percent.

Even though the number of excellent results is more in LCDCP group, it is not statistically significant as per chi square test ($\chi^2 = 0.136$ and P value = 0.7125)

EXCELLENT RESULT WITH DCP:



Pre-Op

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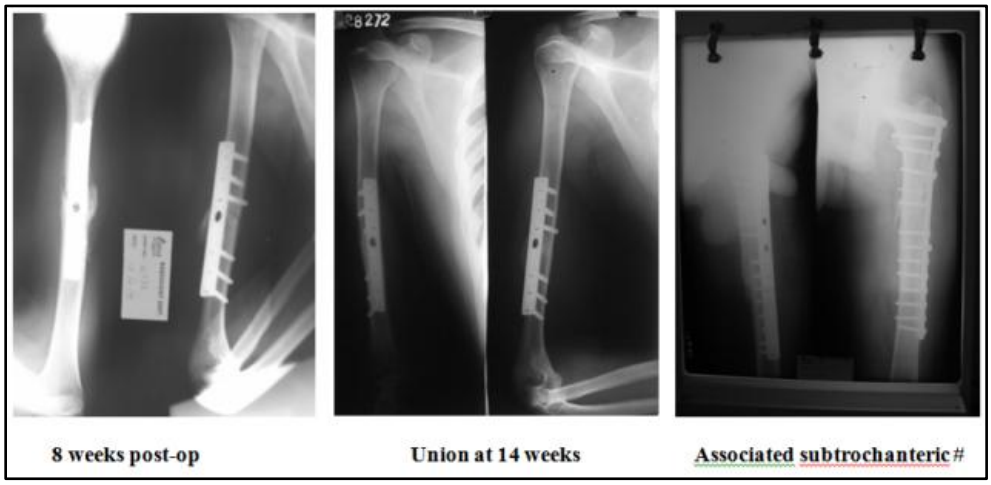
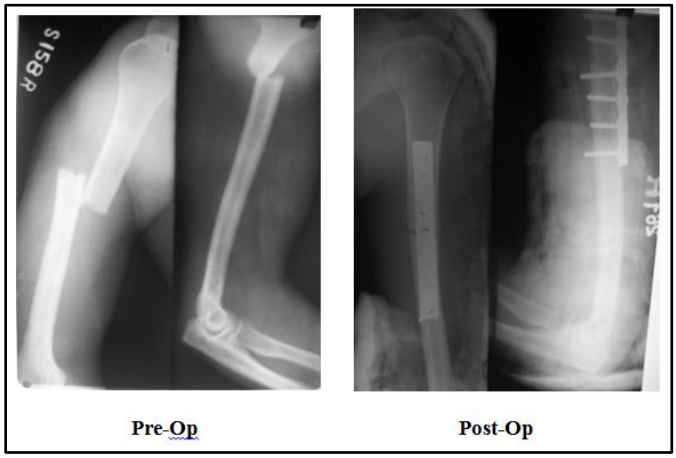


8 weeks post-op | Union at 14 weeks | Associated subtrochanteric #

Abduction | External Rotation | Internal Rotation

EXCELLENT RESULT LCDCP:



Pre-Op | Post-Op

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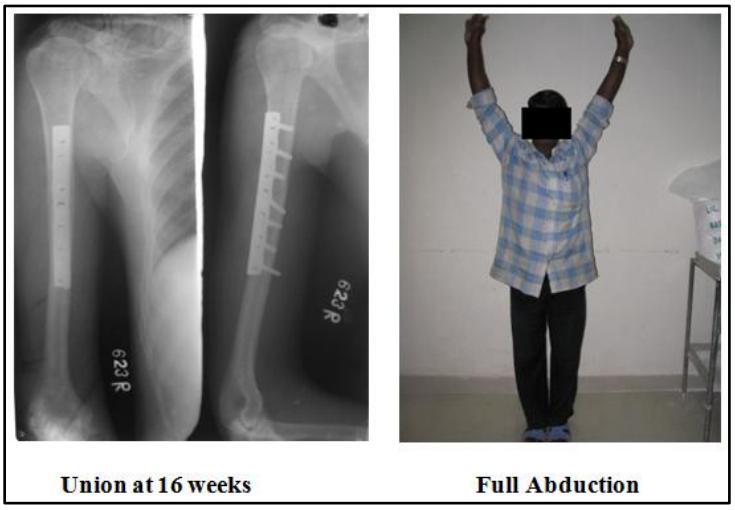

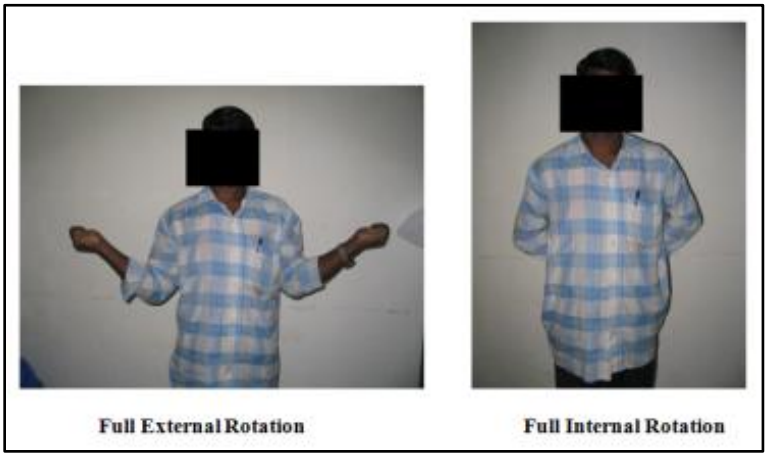

CONCLUSION: In our study we conclude that open reduction and internal fixation by compression plate technique using DCP or LCDCP gives excellent results with low complication rates and can be used whenever surgical treatment is indicated.

The difference in time for union between LCDCP and DCP was 0.67 weeks. This was not significant as per student T test. The difference in the mean DASH score was 0.88. This was also not statistically significant.

Since we found no statistically significant difference in the time taken for union and the functional outcome between the two groups, we conclude that the theoretical advantage of the LCDCP does not translate into clinical advantage when used in Diaphyseal fractures of the humerus.

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