ORIGINAL RESEARCH PAPER
Volume - 10 | Issue - 08 | August - 2021 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

A STUDY OF SURGICAL MANAGEMENT OF DISTAL FEMORAL FRACTURES IN ADULTS USING LOCKING COMPRESSION PLATE

Orthopaedics

Prof. Dr. K J Reddy	MS(PGI),DNB,FRCS(UK),FRCS (ORTHO)
Prof. Dr.Chavan Jai Krishna*	MBBS,D.ORTHO,DNBORTHO,FAIMS,AAOS(USA). *Corresponding Author
Dr. V. Chaitanya	MS (Ortho), Former PG,SVS Medical College Hospital ,Mahabubnagar, 509002 (TS).

ABSTRACT

The Distal femoral Locking compression plate is an optimal tool for fixation of fractures of distal femur of type A and C and in osteoporotic bones. It provides rigid fixation in the region of femur, where a widening canal, thin cortices and frequently poor bone stock make fixation difficult. Surgical exposure for plate placement requires significantly less periosteal stripping and soft tissue exposure than that of normal plates. Orthopaedic surgeons experience with locking compression plating technique will find it a useful technique. However careful understanding of its basic principles, accurate positioning and fixation, identification of appropriate fracture patterns for use of LCP is essential to avoid complications like generation of non- union. the LCP condylar plate represents an evolutionary approach to the surgical management of distal femoral fractures, but it does not completely solve the age-old problems of nonunion and mal-union. Locking Compression Plate is an important armamentarium in treatment of fractures of distal end femur, especially when fracture is severely comminuted and in situations of osteoporosis. However as some of the other recent studies show more incidence union related problems and poor functional outcomes, a more comprehensive study with longer follow up periods is essential to throw more light into the advantages, complications and possible disadvantages of the use of Locking Compression Plate with special attention to the long term outcomes.

KEYWORDS

INTRODUCTION

Due to rapid industrialization and growth of the automobile industry, the comforts have increased but so are the catastrophic road traffic accidents.Most of the high velocity injuries are associated with fractures somewhere in the body but one of the important and commoner type of fractures are the fractures occurring at the distal end of the femur.The incidence of distal femur fractures is approximately 37 per 1,00,000 person-years. Distal femoral fractures mainly arise from two different injury mechanisms. They are often caused by high energy trauma mainly sustained in road traffic accidents. Open injuries with considerable comminution of condyles and metaphysis are frequently seen, as is low energy trauma, relating to elderly patients with severe osteoporosis frequently seen as periprosthetic fracture. In high-energy trauma, the problem of restoring the function in a destroyed knee joint persists. Complex knee ligament injuries frequently occur additionally to extensive cartilage injuries. In elderly patients, extreme osteoporosis represents a particular problem for anchoring the implant. The incidence of these fractures are high in elderly osteoporotic patients along with a high incidence in young patients showing a bimodal distribution**.** Most surgeons agree that distal femur fractures need to be treated operatively to achieve optimal patient outcomes. Although good internal fixation results have already been reported with these fractures over 30 years ago the number of revisions for non union, loss of reduction and implant failure has been high.The options for operative treatment are traditional plating techniques that require compression of the implant to the femoral shaft (blade plate, Dynamic Condylar Screw, non-locking condylar buttress plate), antegrade nailing fixation, retrograde nailing, sub muscular locked internal fixation and external fixation.However, as the complexity of fractures needing treatment has changed from simple extra-articular supra- condylar types to inter-condylar and metaphyseal comminuted types, these implants may not be ideal. Double plating, and more recently, locked plating techniques have been advocated.

However, with double plating there is often extensive soft tissue stripping on both sides of the femur, resulting in reduced blood supply and potential non-union and failure of the implants.Most commonly used implant for the fixation of distal femur fractures are Fixed angle devices, usually in the form of Dynamic Condylar Screw (DCS) system, which is a supracondylar plate combined with a lag screw. This two piece device is more forgiving and allows correction in the sagittal plane after the lag screw is inserted.The LCP is a single beam construct where the strength of its fixation is equal to the sum of all screw-bone interfaces rather than a single screw's axial stiffness or pullout resistance as seen in unlocked plates. Its unique biomechanical function is based on splinting rather than compression resulting in flexible stabilization, avoidance of stress shielding and induction of callus formation. Further when it is applied via a minimally invasive technique, it allows for prompt healing, lower rates of infection and reduced bone resorption as blood supply is preserved.Internal fixation with locking plates creates a toggle free, fixed angle construct. The introduction of plates with the option of locked screws has provided the means to increase the rigidity of fixation in osteoporotic bone or in the presence of periarticular or juxta-articular fractures with a small epiphyseal segment. The implant offers multiple points of fixed-angle contact between the plate and screws in the distal part of femur, theoretically reducing the tendency for varus collapse that is seen with traditional lateral plates.The DF-LCP is a further development from the LISS which was introduced in the mid to late 1990's. The main difference between the DF-LCP and the LISS is that the LISS utilizes an outrigger device for shaft holes, functioning essentially as a locking guide jig, which is attached to the distal part of the plate and guides the placement of the proximal locking screws. The shaft holes on the DF-LCP are oval allowing for the options of a compression screw or a locking screw which leads to a more precise placement of the plate, as it is able to be compressed more closely to the bone. Since there have been less published studies focusing specifically on the LCP plate, this study will help us in defining the role of locking compression plate in the treatment of distal femur fractures. The study is justified for the fact that it will be one of the solutions for the age old complications associated with the treatment of distal femoral fractures with traditional fixed angle plates and nails as postoperative loss of reduction (varus collapse) and malalignment due to their inherent lack of rigidity and in some cases, eventual implant failure and other complications.

AIMS & OBJECTIVES

To study and analyze the effectiveness of the surgery of the distal femoral fractures using Locking Compression Plate based on fracture union, complications, recovery, return to work and overall functional outcome using standard criteria and statistical methods of analysis.

CLASSIFICATION
FRACTURE LOWER END OF FEMUR

There is no universally accepted method of classification for fracture lower end of femur. Essentially all classifications distinguish between extra-articular, intra-articular and isolated condylar fractures.

Fractures are further subdivided according to the degree and direction of displacement, the amount of comminution, and the involvement of the joint surfaces. Unfortunately, anatomical fracture classifications fail to address the conditions commonly associated with supracondylar femur fractures, which often influence treatment or outcome. These factors, which play a dynamic role in management, determine the 'personality' of the fracture.

AO-ASIF classification has been used in the present study.
AO Classification:
TYPE A: Extra-articular fractures

A1:
Simple fractures
A.1.1 Avulsion fracture of the medial or lateral epicondyle.
A.1.2 Fracture of metaphysis oblique or spiral
A.1.3 Fracture of metaphysis transverse

A2:
Metaphyseal wedge fractures
A.2.1 Wedge intact
A.2.2 Lateral comminuted wedge
A.2.3 Medial comminuted wedge

A3:
Complex metaphyseal fracture
A.3.1 With a split intermediate segment
A.3.2 Irregular but limited to the metaphysis
A.3.3 Irregular and extending into the diaphysis.

TYPE-B: Fractures are partially articular
Type B1:
Lateral condylar fractures in sagittal plane
B.1.1 Simple through intercondylar notch
B.1.2 Simple through weight bearing surface
B.1.3 Comminuted

Type B 2:
Medial condylar fracture in sagittal plane
B.2.1 Simple through intercondylar notch
B.2.2 Simple through weight bearing surface
B.2.3 Comminuted

Type B3:
Coronal fracture of femoral condyles

TYPE-C: Fractures which are intra-articular
C1: Simple fractures of both articular surface and metaphysis
C.1.1 slightly displaced T or Y shaped fractures
C.1.2 markedly displaced T or Y shaped fractures
C.1.3 distally situated T fractures with horizontal element involving epiphysis.

C2: Simple fractures of articular surface and comminution of metaphysis.
C.2.1 With intact wedge
C.2.2 Comminuted wedge
C.2.3 Complex

C3: Comminution of articular surface
C.3. 1 Metaphyseal simple
C.3.2 Metaphyseal comminuted
C.3.3 Metaphyseal comminuted extending into the shaft.

AO-ASIF Classification of Distal End Femur Fracture

MECHANISM OF INJURY
The mechanism of fracture lower end of femur or upper end of tibia in most cases is axial loading with varus or valgus as rotational forces. High velocity trauma is culprit in young generation where considerable fracture displacement, communition and open wound may be seen. In the elderly with osteoporotic bones, trivial trauma on flexed knee can cause this fracture

CLINICAL FEATURES
The patient with a fracture around knee is likely to show symptoms of shock due to the loss of blood into the muscles of the thigh or into joint. Locally there will be swelling of the thigh/leg, haemarthrosis, deformity and tenderness. The presence of abnormal mobility and shortening of the limb will complete the clinical picture.

One must examine the distal pulsation in the dorsalis pedis and posterior tibial arteries and tibial and peroneal nerve injury should be ruled out.

TREATMENT
Once diagnosed treatment decisions are based on both the characteristics of the fracture and patient factors. Treatment challenges are presented by patients with osteoporotic bone, open fractures with significant bone loss, and fractures with short articular segments.

Nonoperative Treatment
Nonoperative treatment may be chosen for non- or minimally-displaced fractures in low- demand elderly patients. Nonoperative treatment may consist of either skeletal traction or initial splinting and mobilization with limited weight bearing and eventual transition to either a cast or functional brace. Radiographs are typically obtained at weekly to biweekly intervals for the first 6 weeks to ensure that the fracture reduction is maintained. Gradual progressive weight bearing and joint mobilization are allowed based on the clinical and radiographic progression of fracture healing. In general, however, nonoperative treatment does not work well for displaced fractures. Nonoperative treatment for displaced fractures is reserved for those patients who cannot tolerate surgery.

Operative Treatment
Operative treatment is indicated for displaced fractures, open fractures, and those associated with a vascular injury. Treatment goals include anatomical reduction of the articular surface, restoration of limb alignment, early postoperative knee range of motion (important for articular cartilage nutrition), and early patient mobilization. *Initial management* of distal femur fractures typically includes a well-padded long leg splint to improve patient comfort and prevent further soft tissue injury. Other options or temporary stabilization include a skeletal traction pin through the proximal tibia.

FRACTURE LOWER END FEMUR DEFINITIVE MANAGMENT
Multiple options exist for the definitive treatment of distal femur fractures and include external fixation, intramedullary nailing, and plate osteosynthesis with either open reduction or internal fixation or minimally invasive plate osteosynthesis. Likewise, multiple different plating options are available and include conventional buttress plates, fixed-angle devices, and locking plates.

External Fixation
External fixation is typically reserved for those patients with open fractures with bone loss, vascular injury, associated significant soft tissue injuries, or extensive comminution. For fractures with articular involvement, articular reconstruction is performed first, using either open reduction and limited internal fixation or closed reduction and percutaneous fixation with independent screws. Articular reconstruction is then followed by application of the external fixator. Complications related to the use of external fixation for definitive treatment of distal femur fractures include septic arthritis, osteomyelitis, pin tract infection (thought to be due to the large soft tissue envelope of the femur), loss of reduction, delayed union or nonunion requiring bone grafting, and limited knee motion requiring either manipulation under anesthesia or quadricepsplasty.

Intramedullary Nailing

Intramedullary nail fixation is reserved for fractures with enough intact distal femur to allow for interlock fixation. The main indication for using an intramedullary nail is an AO/OTA type A fracture. However, both antegrade and retrograde nailing has been used successfully in the management of high-energy AO/OTA type C 1 and 2 fractures.As the retrograde intramedullary nailing technique has evolved, it has become more commonly used for distal femur fractures than antegrade nailing. This is likely due to the greater number of distal fixation options available with retrograde nailing. As with plating distal femur fractures, indirect fracture reduction and minimally invasive plating techniques have also evolved.

Plating techniques

In the 1990s, the success of indirect reduction techniques for distal femur fractures were reported using conventional implants including the dynamic condylar screw, angled blade plate, and condylar buttress plate.

Open reduction and internal fixation of comminuted intercondylar and supracondylar fractures of the femur demand experience and surgical skill. Extensive exposure and dissection are required. A complete set of instruments and familiarity with their use are required for this method of fixation. Strict adherence to basic principles and technique is required to prevent unsatisfactory results The development of anatomically-contoured plates, with insertion jigs that allow for percutaneous insertion of the screws in the shaft of the plate, allows these systems to be more readily used in a minimally invasive fashion.

COMPLICATIONS OF SUPRACONDYLAR FRACTURE FIXATION

Early complications: - Some of the known complications are Vascular complications -Injury to the popliteal artery is the most common ,Early infection, Failure of reduction, Early failure of fixation,poor bone stock, poor patient compliance with postoperative care and poor surgical planning and execution

Late complications:- Late infections, nonunion, malunion, painful internal rotation, knee stiffness, post traumatic osteoarthrosis are the chief late complications. Nonunions are generally rare occurrences and most of them heal well with bone grafting. Knee stiffness is a particular problem that requires careful observation. Immobilization in flexion, early use of CPM, use of epidural analgesia for relief of pain is some of the strategies used to prevent this complication. Post traumatic arthrosis a well known complication of periarticular fractures can be seen in significant number of cases. Prevention of this complication, is at least theoretically possible by anatomic education of joint surfaces, correct alignment, and maintenance of knee motion

LOCKING COMPRESSION PLATE USED IN THIS STUDY

We have used an Indian made LCP (316L) in treatment of fracture lower end of femur. It is a prebent fixed angle plate with dual function of achieving compression at fracture site when required and obtaining rigid fixation by locking screw to the plate in turn reducing the plate back out, providing angular stability. The locking screws are self - tapping available in 5mm and 6.5 mm thickness.

ADVANTAGES OF LOCKING COMPRESSION PLATE

1. **Anatomically precontoured:** Reduces soft tissue problems and eliminates the need for plate contouring.
2. **LCP combi-holes:** Intraoperative choice between angular stability and / or compression.
3. **Guiding blocks:** Enable easy and correct mounting of the threaded drill guides in the spoon part of the plate.
4. **Compatible with the LCP and LISS instrumentation:** The plates can be used with the Standard LISS and LCP Large Fragment Instruments. To apply the LISS technique, the LISS aiming arm can also be used.
5. **Limited-contact plate design:** Reduces plate-to-bone contact, thus limiting vascular trauma.
6. **Osteoporotic bones:** Better fixation of fracture in elderly patients.
7. **Unicortical fixation option** of locking screws unlike cortical screws which requires bicortical fixation.
8. **Better preservation of blood** supply of bone due to minimal soft tissue dissection.
9. Maintaining better **articular congruency**.
10. Early ambulation in poly trauma patients.
11. Shorter stay in hospital.
12. Length of the bone is maintained in communited fractures.

PATIENTS AND METHODS

In this study 30 patients with closed distal femoral fractures (distal fifteen cm of femur) were studied. All the cases were treated at SVS HOSPITAL , Yenugonda, Mahabubnagar, between May2012 to Jan 2014 at our institution and followed for a minimum of 6 months. The duration of follow up ranged from 6 months to 18 months.All the fractures in this series were post-traumatic. No pathological fracture was included in the study. Distal femoral fractures in children were not considered. Supracondylar fractures treated conservatively and fixed with other fixation systems like AO blade plate and condylar buttress plate were not included. The following protocol was observed for patients with fracture lower end of femur on arrival. General, systemic examination as well as local examination of the patient. Assessment to rule out head/ chest/ abdominal/ spinal or pelvic injury. Evaluation of patients in terms of: Age,Sex,Mode of trauma,Period between injury and arrival.Musculo-skeletal examination of patient to rule out associated fractures. Stabilization of patient with intravenous fluids, oxygen and blood transfusion as and when required. Careful assessment of injured limb as regards to neurovascular status. Primary immobilization of involved limb in Thomas splint with a cotton pad below the distal fragment and transport of patient to the department of radiodiagnosis in the same. Radiological assessment: Anteroposterior and true lateral views of injured limb including complete knee joint and distal femur/proximal leg.Thorough irrigation and lavage of associated compound injuries with hydrogen peroxide and normal saline followed by povidone iodine padded dressings.Upper tibial skeletal pin traction with a Steinmann or Derham pin drilled under local anesthesia followed by continuous traction given over the Bohler Braun splint was used. Compound fractures were not considered in the study. Injection ATS 1500 IU, Injection AGGS 30,000 IV, broad spectrum injectable antibiotics and analgesics were administered for compound injuries of other parts as and when required.

Patient Selection:

Patients admitted to SVS Hospital, Yenugonda, Mahabubnagar with fracture distal end femur (distal 15 cms of femur).All types of fracture lower end of femur (AO classification A, B & C), Only closed fractures were considered, Pediatric patients and pathological fractures excluded.

INCLUSION CRITERIA

Those patients who are of or above the age of 20 yrs and managed surgically were included in the study. Patients presenting with distal femoral fractures with or without osteoporotic changes were included in the study

EXCLUSION CRITERIA

Patients with open distal femoral fractures ,Children with distal femoral fractures in whom, growth plate is still open. Patients lost in follow - up ,Patients managed conservatively for other medical reasons. Distal femoral fractures with neurovascular compromise

Implant Used:

The plate and screws are manufactured from 316L stainless alloy with gun drilling technique. The locking compression plates are available from 5 holed to 13 holed. With 4.5 mm thickness plate for lower end of femur **anatomically precontoured** plate head with soft edges. Locking screws in the head of the plate for a secure support. The head of the locking screw is threaded which gets locked to the plate as it istightened.

LCP combi-holes in the plate shaft - Intraoperative choice between angular stability and/or compression. **4.5mm LCP** have 50 ° of longitudinal screw angulation and 14° of transverse screw angulation with uniform combi hole spacing. 5 mm and 6.5 mm self tapping locking screws with 3.2mm and 4.3mm drill bits respectively along with threaded drill sleeves are available.

PREOPERATIVE INVESTIGATION:

Hemogram
Blood sugar level, Blood urea level
Serum creatinine level
Liver function test
Blood group and Rh typing Bleeding time, clotting time

$\Big\}$ Done in all patients

 PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

Chest X-ray PA view, Doppler if required, ECG, 2D echo and other investigations done as per requirement during the anaesthetic evaluation

PREOPERATIVE PLANNING AND PREPARATION:
Fractures were classified with the help of radiographs according to the AO-ASIF classification. Preoperative calculation was done on radiographs to ascertain the size of the plate, accurate size of locking, cortical and cancellous screws after subtraction of the magnification factor.The limb to be operated was prepared. One gm of third generation cephalosporin was injected the night before surgery and early morning on the day of surgery before shifting the patient to the operation theatre.

SURGICAL PROEDURE:
Patient is placed supine on a radiolucent table with a pillow below the knee, the entire injured extremity and ipsilateral iliac crest are prepared and draped. Tourniquet applied and inflated. Lateral incision is made parallel to the shaft of the femur, beginning at the Gerdy tubercle and extending proximally far enough to permit application. Longitudinal incision is made through the fascia lata, and extended distally into the iliotibial band. The distal part of the incision is extended through the lateral joint capsule and synovium, avoiding injury to the meniscus.More proximally, the fascia overlying the vastus lateralis muscle is incised and the muscle reflected anteriorly off the intermuscular septum and perforating vessels are identified and ligated or coagulated. Minimal Stripping of soft tissue necessary for application of the plate and reduction of the articular surface is done. To preserve their vascularity, attempt is not made to expose and anatomically reduce comminuted anterior and metaphyseal fragments. Often the shaft of the femur is wedged between two condyles; if so, by applying traction to the leg with the knee flexed, wedged shaft of femur is displaced. Quadriceps mechanism and the patella are reflected medially to expose the entire lower end of the femur.

Reduction of condyles
To aid in reduction of the condyle, a Steinmann was drilled into the lateral surface of the lateral condyle, If needed, a similar pin was placed in the medial condylar fragment. Using these pins as levers, manipulation and reduction of the two major condylar fragments was done to restore the articular surface and patellofemoral groove. Two condyles were fixed together with multiple 2-mm Kirschner wires. Medial and lateral condyles together were fixed with 6.5-mm cancellous screws directed lateral to medial, taking care not to interfere with the subsequent path of other cancellous screws of locking compression plate. Second screw was placed without a washer, slightly anterior and proximal to the first. Kirschner wires used for temporary fixation was removed.

The next step is reduction of the condyles to the femoral shaft. When using the plate as a reduction aid, the compression screw draws the bone towards the plate and uses the contour of the plate to reduce the fracture in the coronal plane (figure 18). The plate does not aid in the sagittal plane reduction or restoration of limb length. Reduction of the fracture was assisted keeping folded pillow below the knee which prevented posterior angulation of distal fragment with manual traction. Once the fracture is reduced, supplemental locking screws were then added to create a fixed-angle construct. The compression mode can also be used to address reduced articular fractures through the plate, or can be used in simple fracture patterns.

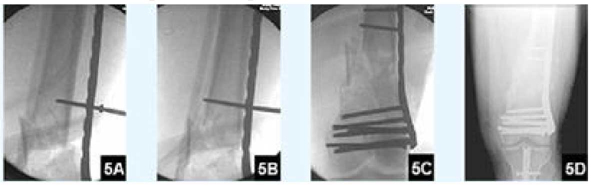


Fig : An example of the hybrid fixation technique. After sagittal alignment and length were restored and provisional k-wire fixation of the distal articular block was done, the coronal plane is malreduced (A). A bicortical screw is placed through the anatomically contoured plate which reduces the coronal plane alignment as the screw pulls the bone towards the plate (B). Final AP view after placing locking screws (C). Healed distal femur fracture without bone grafting (D).

SURGICAL PROCEDURE

DISTAL FEMORAL LCP PLACED

CANCELLOUS BONE DRILLED AND LOCKING CANCELLOUS SCREWS PLACED

CORTICAL BONE DRILLED AND LOCKING CORTICAL SCREWS PLACED

PLATE WITH ALL SCREWS PLACED

WOUND CLOSED IN LAYERS AND PLACED OVER A DRAIN

POSTOPERATIVE
Patients' vitals were monitored. Foot end elevation was given overnight, drain was monitored. Antibiotics were given as per the hospital protocol. Analgesics were given as per the patient compliance. Blood transfusion was given depending upon the preoperative general condition and intraoperative blood loss.

MOBILISATION
Splints were removed and mobilization of the limb started on the 3^{rd} or 4^{th} day postoperatively. Mobilization with Non weight bearing was started from the first post operative week till 6-8 weeks depending on the fracture pattern and then partial weight bearing after confirmation of beginning of healing process till fracture union.

FOLLOW UP
All patients were followed up at 6^{th} 10^{th} 14^{th} 18^{th} week and 6 weeks thereafter till fracture union is noted. Subsequently at 6^{th} month 9^{th} month and 1 year. During follow up patients were assessed clinically, radiologically and functionally by NEERS criteria.

CLINICAL & RADIOLOGICAL EVALUATION
1 CASE
M/32 years/RTA/Left C2 Type

Pre Operative

Immediate Post Operative

8 weeks followup

14 weeks followup

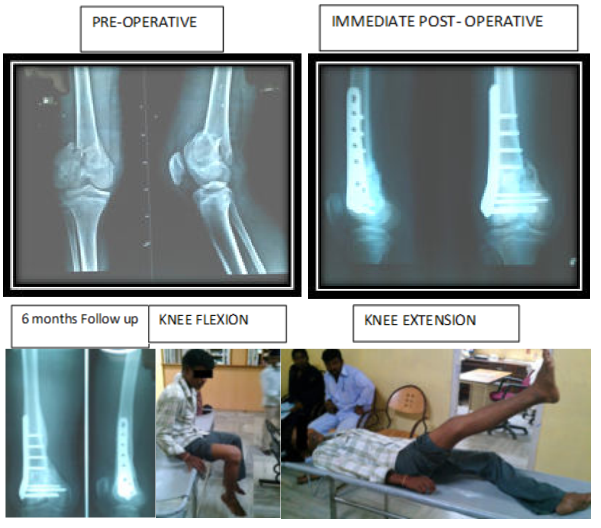
Knee Extension

Knee flexion

Neers score at 6 - 8 months: 89 points - Excellent

PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

2 CASE
M/20 Years/RTA/Right-C3 Type



Neers Score at 6-8 months:86 points -Excellent

RESULTS

In this study, 30 distal femoral fractures were treated using the distal femoral locking compression plate. All cases were fresh, and all fractures were closed. Cases were followed up from a minimum of 6 months to maximum of 18 months.**Epidemiology:** 20 patients were males and 10 patients were females. The median age was 40yrs years ranging from 20 - 75 years. 16 patients were with fracture on right side 14 on left side. **Mechanism of injury**: 23 of the fractures which includes about 76.66%, were caused by road traffic accidents and 3 were due to accidental falls making 10% of cases, one was due to assault and 3 cases were due to other causes. All fractures were fresh and closed.**Classification:** Of the 30 'lower end of Femur' fractures, 6 were Mullers type A1; 3 was Mullers type A2 ; 3 cases were of muller type A3, 2 were Mullers type C1; 9 were Mullers type C2 and remaining 7 were Mullers type C3. All fractures were closed.

Associated injuries: 9 patients had associated injuries.

Perioperative:
All patients were treated with open reduction and internal fixation using Locking Compression Plate. All patients were operated within 10 days. Depending on the medical and surgical comorbidities the injury-surgery interval lasted from 2 days to 10 days. Average time duration of surgery was 111 minutes with shortest duration being 90 min and longest being 130 min. The size of plate was selected based on the type of fracture. 7 to 9 holed plates were used more commonly for lower end of femur.

Bone grafting: 8 of the cases had bone grafting of which 6 had primary bone grafting and two patients had secondary bone grafting done at the end of 5 months for delayed union and both cases went on to union after secondary bone grafting.

Union: Of 30 patients, 23 Patients (76.66%) showed radiological union within 18 weeks and 84% cases united within 22 weeks. one patient had implant failure. average time taken for union was 16.6 weeks. Two cases went for delayed union and three cases went for non-union.

Range of motion: Average flexion in this study was 109^0 with 50% patients having knee range of motion more than 100^0. Average knee extensor lag in this study was 2.4 degrees with only 4 patients with lag more than 5^0

Complications:
Non-union: 3 out of 30 cases went for non-union out of which 2 were due to deep infection who were managed with debridement and Ilizarov ring fixator and the other was a gap non union which is being planned for revision.

Limb length discrepency: Of 30 patients, 7 had shortening 3 patients with upto 1cm, 2 cases with 1-2 cm and 2 cases over 2 cm shortening.

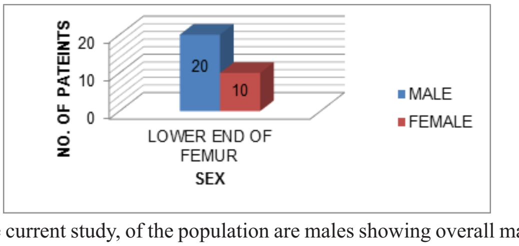
Malalignment: In this study, only 2 patients had mal-alignment of over 5 degrees and 4 patients had less than 5 degrees of mal-alignment.

Infection: 2 of the patients had superficial surgical site infection which was controlled before the patients were discharged from the hospital. 2 patients had deep infections and were treated with debridement and antibiotics but went on for non-unions and were managed with Ilizarov ring externall fixator.

Functional outcome: Functional outcome was measured using NEER's scoring system and was done at the end of 6- 8 months (average of 6 months).Excellent results- 17 (56.66%) Good results-8 (26.66%)Fair results-2 (6.66%)poor results-3 (10%).Results are analyzed in charts and tables below using statistical methods of analysis. The data collected in the present study was analyzed statistically by SPSS version 17 software appropriate statistical test were used to determine the efficacy of outcome such as chi-square test, p-values for significance along with means and standard deviations for descriptive studies wherever it was appropriate.

Table-1: Sex Distribution

SEX	LOWER END OF FEMUR	PERCENTAGE
Male	20	66.6
Female	10	33.3



In the current study, of the population are males showing overall male predominance.

Table-2 : Age Distribution
There is predominance of younger population in the study as there is high incidence of RTA's in the demography.

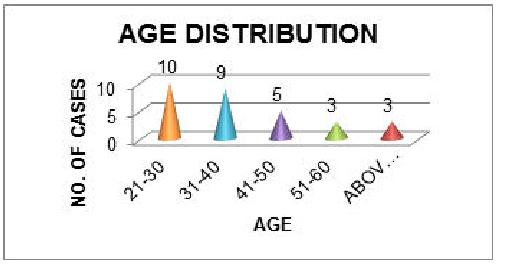
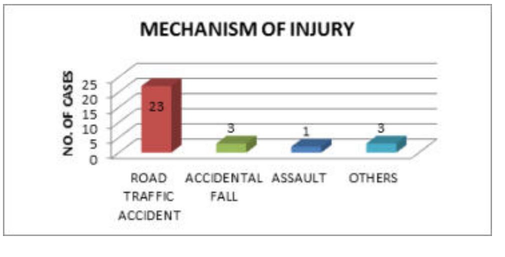


Table - 3:mechanism Of Injury

AGE DISTRIBUTION	LOWER END OF FEMUR	PERCENTAGE
21-30	10	30
31-40	9	27
41-50	5	15
51-60	3	9
Above-60	3	9
TOTAL	30	100

MECHANISM OF INJURY	LOWER END OF FEMUR	PERCENTAGE
ROAD TRAFFIC ACCIDENT	23	76.6
ACCIDENT FALL	3	10
ASSAULT	1	3.3
OTHERS	3	10

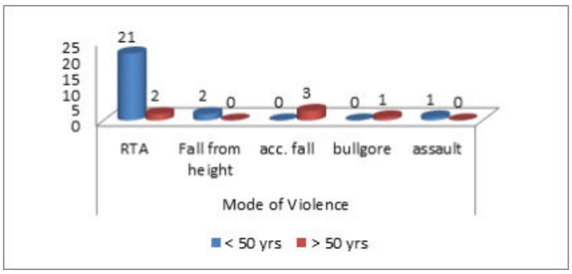


RTA constitutes to 76.6% of total fractures. Trivial trauma is the cause in 10% of population and rest of the injuries described elsewhere previously are due to significant trauma. This can be related to high percent of young population.

Table 4: Relationship Between Age And Mechanism Of Injury

Age group		Mode of Violence					Total
	No. of patients	RTA	Fall from height	acc. fall	bullgore	assault	
< 50 yrs	No. of patients	21	2	0	0	1	24
	%	87.5%	8.3%	.0%	.0%	4.2%	100.0%
> 50 yrs	No. of patients	2	0	3	1	0	6
	%	33.3%	.0%	50.0%	16.7%	.0%	100.0%
Total	No. of patients	23	2	3	1	1	30
	%	76.7%	6.7%	10.0%	3.3%	3.3%	100.0%

Chi square = 18.587 p value = 0.001



Relationship of age was compared with mechanism of injury it was observed that in patients with age < 50 yrs RTA was seen to be present in 87.5 % which was significantly more (p=0.001) than other forms of injury compared to patients with age > 50 yrs where accidental fall constituted 50 % of cases which was significantly more (p=0.001) than other forms as well as accidental falls in age < 50 yrs.

Table -5 Relationship Between Sex And Cause Of Injury

SEX	RTA		FALL		ASSAULT		OTHERS	
	NO.	PERCENT	NO.	PERCENT	NO.	PERCENT	NO.	PERCENT
MALE	17	56.66%	1	3.30%	1	3.33%	1	3.30%
FEMALE	6	20%	2	6.60%	0	0	2	6.60%

RTA appears as the most common cause in males and females and this may be related to younger age group of the study overall.

Table – 6 Side Affected

SIDE AFFECTED	NO.OF CASES	PERCENTAGE
RIGHT SIDE	16	53.55%
LEFT SIDE	14	46.66%

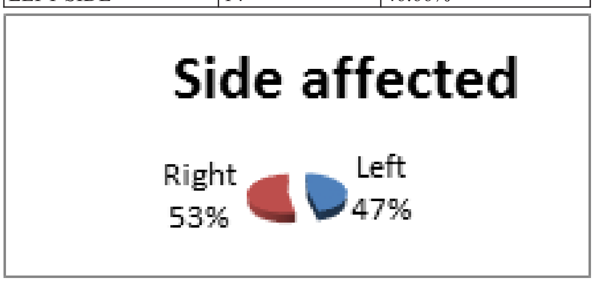


Table - 7 : Type Of Fracture (muller's)

MULLER'S TYPE	NO.OF CASES	PERCENTAGE
A1	6	20%
A2	3	10%
A3	3	10%
B1	0	0%
B2	0	0%
B3	0	0%
C1	2	6.60%

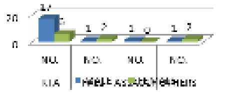
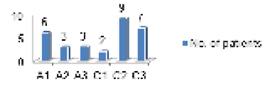


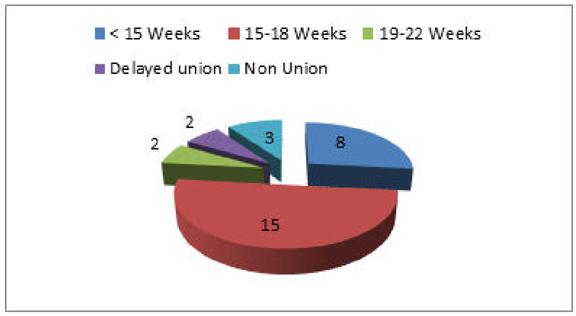
Fig 3: Distribution based on Mullers classification



Intraarticular and comminuted fractures traditionally have a bad prognosis. The incidence of intraarticular fractures are high in this study group. This can be related to high incidence of high velocity injuries like RTA, and fall from height.Intraarticular fractures constitute to 60% of cases and comminuted fractures C3 and A3 constitute to 33.3% together. No cases of partial articular fractures were included as most of them were managed with other methods of fixation like butress plate and C- C screw fixation.

Table - 8 Time To Radiological Union

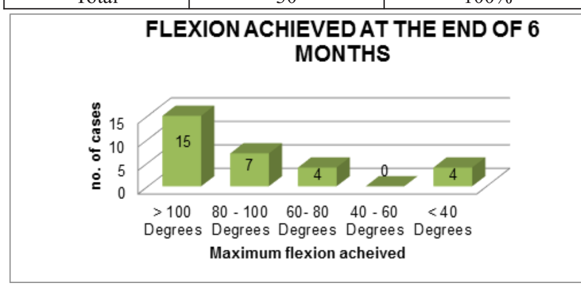
RAD. UNION SEEN AT	No. of cases	PERCENTAGE
< 15 weeks	8	26.66%
15-18 weeks	15	50%
19-22 weeks	2	6.66%
Delayed union	2	6.66%
Non-Union	3	10%
MEAN	16.6 weeks	



26.6% cases united within 15 weeks of time and overall 76.66% cases united by 4 months (16 weeks). 2 cases went for delayed union and 3 cases went for non-union. The mean time for the union was **16.6** weeks and excluding the two cases of delayed union, the mean time for union was **15.6** weeks with a standard deviation of **1.63.**

Table- 9: Knee Flexion

Knee Flexion	No. of cases	Percentage
>100 Degrees	15	50%
80-100 Degrees	7	23.33%
60-80 Degrees	4	13.33%
40-60 Degrees	0	0%
<40 Degrees	4	13.33%
Total	30	100%



Knee flexion was more than 100 ^{0} in 50% of study group. The average knee flexion was greater than 110^0,in 43.3% of the study group and which was considered optimal for daily activities by Laubethal and is less than 400 in 13.33% of study group

Table - 10 Limb Length Discrepency

SHORTENING	NO. OF CASES	PERCENTAGE
0.5-1 cm	3	10%
1-2 cm	2	6.66%
>2cm	2	6.66%
Total	7	23.33%
No Limb length Discrepency	23	76.66%

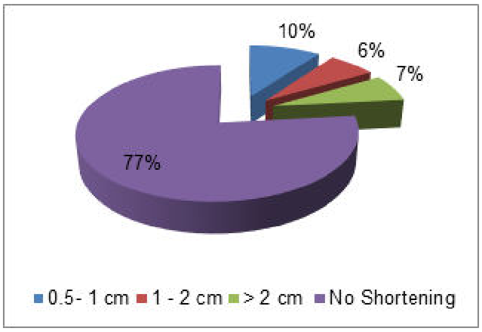
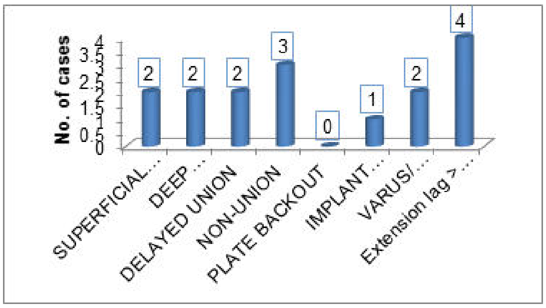


Table - 11 Complications

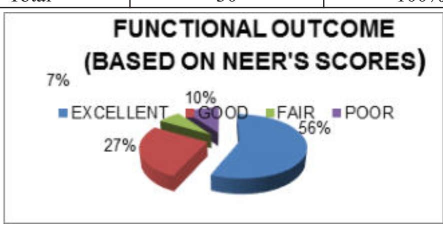
COMPLICATIONS	NO.OF CASES	PERCENTAGE
Superficial Infection	2	6.66%
Deep Infection	2	6.66%
Delayed Union	2	6.66%
Non-Union	3	10%
Plate Backout	0	0%
Implate failure- Screw/Plate Breakage	1	3.33%
Varus/Valgus of >5 Drgrees	2	6.66%
Extension lag >5 degrees	4	16.66%



In the study, there were 3 cases (10%) of non union which had poor results among which, 2 cases were infected non-unions and one case was diagnosed as gap non-union which had a complication of screw breakage which was managed accordingly. Varus and valgus malalignment of $< 5^{\circ}$ was seen in 4 cases (2 each).Extension lag of 5° / less than $5^{\circ}$was seen in 8 cases and greater lag was seen in 4 cases.

Table- 12 Functional Results (based On Neer Scoring)

Neer Grade	No. of cases	Percentage
Excellent	17	56.66%
Good	8	26.66%
Fair	2	6.66%
Poor	3	10%
Total	30	100%



Functional outcome was assessed using NEER score at the end of 6 months to 8 months depending on the patient followup. The scores were excellent in 56.66% of the study group. Good to excellent results were seen in 83.33% of the study group.

DISCUSSION

Management of distal femoral fractures is challenging and often complicated by concomitant injuries and open fractures. The primary goal is to restore the axis and rotation of the injured femur and to restore the articular surface if necessary. In high-energy injuries to the lower limb a combination of metaphyseal and intra-articular injuries is found frequently. In order to treat these complex injuries, the specific characteristics of the device used are important. Mechanically, it should provide high primary stability and yet enough flexibility to allow dynamic osteosynthesis, it should be applicable in an angular stable mode, and maintain the reduction until union. In these complex injuries, the time to complete bony union often exceeds six months. These mechanical properties should go along with an easy and flexible way of application.one such implant with all the aforementioned features is the LCP.In this study 30 fractures of distal femur were treated with LCP . Overall outcome of the surgical management of fracture lower end of femur using LCP was assessed in terms of regaining the lost knee function using NEER'S Score. All cases studied in the series were closed. 20 patients were males and 10 patients were females. The median age was 40 years ranging from 20 - 75 years.23 of the fractures were caused by road traffic accidents and 3 were due to fall and one was due to assault and 3 were due to other causes (one case of Bull gore injury and two were due to fall from height). 16 patients were with fracture on right side and 14 on left side.Of the mechanisms of injury, all the younger patients (2nd to 4th decade) had a high energy trauma like the road traffic accident or fall from height or assault, and trivial trauma was the most common cause of fracture in older age group. In this study, more number of cases were under 50 yrs of age due to high incidence of road traffic accidents in our demography. half of the patients beyond 50 yrs had a trivial trauma as the cause of fracture This observation is consistent with previous literature by various studies one of which is by **Martinet et. al** . who reviewed, between 1980 and 1989, reports on 2,165 fractures of the distal part of the femur (1,051 women and 1,114 men) which were collected by AO Documentation and were analyzed. They concluded that the number of fractures showed a bimodal pattern with a marked variation in the number of fractures in relation to gender and age. A larger prevalence of fractures was observed either in young men (about 20 years old, traffic or sport) and in old women (about 70, fall at home, osteoporosis). The LCP is a single beam construct where the strength of its fixation is equal to the sum of all screw-bone interfaces rather than a single screw's axial stiffness and pullout resistance in unlocked plates. Its unique biomechanical function is based on splinting rather than compression resulting in flexible stabilization, avoidance of stress shielding and induction of callus formation [9]. When applied via a minimally invasive technique, it allows for prompt healing, lower rates of infection and reduced bone resorption as blood supply is preserved. The DF-LCP is a further development from the LISS, which was introduced in the mid to late 1990's [55]. The main difference between the DF-LCP and the LISS is that the LISS utilizes an outrigger device for shaft holes, functioning essentially as a locking guide jig, which is attached to the distal part of the plate and guides the placement of the proximal locking screws. The shaft holes on the DF-LCP are oval allowing for the options of a compression screw or a locking screw. This leads to a more precise placement of the plate, as it is able to be compressed more closely to the bone. Many standard studies used LISS technique for fixation which is a minimally invasive technique using the DF-LCP some of which are considered here for comparision with present study. Comparing the present study results with standard studies, in a study by **Schutz M, Muller M et al**[6]. Internal fixation using the LISS was performed at an average of 5 days (range: 0-29 days) after the injury. 48 fractures were operated within first 24 hours. Revision operations were required for 2 cases of implant breakage. 4 cases had implant loosening and 7 debridements to deal with infections. The study showed clearly that when working with LISS, primary cancellous bone grafting was not necessary. 5% non- union was observed.In the current study, primary bone grafting was used in 6 cases to promote union in cases of comminuted fractures (A2,A3, C2, C3) as all the cases were reduced by open reduction and internal fixation as LISS technique was not used, though we used minimally invasive approach in certain cases for proximal screw placement. **Weight and Collinge**[73] retrospectively evaluated the use of the LISS locked plating construct in 22 distal femur fractures in 21 patients. All fractures achieved union at a mean of 13 weeks (range, 7 to 16 weeks) without the need for secondary intervention. There were no implant failures in this patient cohort; at a mean of 19 months of follow- up, knee range of motion was 5 to 114 degrees.These results are consistent with the current study except for secondary intervention was needed in few of our cases, secondary bone grafting in two cases for delayed union, two due to infection, and one due to gap non-union which is planned for revision . As the reduction method is open reduction, the union percentage in the current study was 90% and radiological union achieved was longer than the Weight and Collinge study probably due to the same reason that we opened the fracture site.In a similar retrospective evaluation of LISS plate fixation for 103 distal femur fractures, **Kregor et al** reported a 93% union rate without secondary bone grafting. The remaining 7 cases went on to uneventful union subsequent to bone grafting procedures. At a mean follow-up of 14 months, the mean knee range of motion in this cohort was 1 to 109 degrees. Implant failure in the form of proximal screw loosening occurred in 5 cases, each requiring revision surgery. In this study, primary bone grafting was used in cases of severe comminution in selected patients as we were opening the fracture site and evacuating the fracture hematoma and also secondary bone grafting was done in 2 cases of delayed union .The results are consistent with Kregor et al study in terms of union and function.**Yeap, E.J., and Deepak, A.S** conducted a retrospective review on eleven patients who were treated for Type A and C distal femoral fractures (based on AO classification) between January 2004 and December 2004. All fractures were fixed with titanium distal femoral locking compression plate. The patient's ages ranged from 15 to 85 with a mean of 44. Clinical assessment was conducted at least 6 months post-operatively using the Schatzker score system. Results showed that four patients had excellent results, four good, two fair and one failure.The results are consistent with the current study**Zlowodzki et al**[61] combined these series (n=327) and evaluated the outcomes as part of a systematic literature review. Average nonunion, fixation failure, deep infection, and secondary surgery rates were 5.5%, 4.9%, 2.1%, and 16.2% respectively. Some of the technical errors that have been reported for fixation failure have involved waiting too long to bone graft defects, allowing early weight bearing, and placing the plate too anterior on the femoral shaft. **Vallier et al** in his study concluded that locking plates should only be used when conventional fixed-angle devices cannot be placed. They noted the significant added cost of locking plates. To decrease the risk of implant failure with locking plates, they recommended accurate fracture reduction and fixation along with judicious bone grafting, protected weight bearing, and modifications of implant design.**Henderson CE** et al Reviewed the literature on Locking plate for acute distal femur fractures published from 2000 to 2011 in a total of 18 studies and observed that rate of complications related to healing ranged from 0% to 32% in these studies. Implant failures occurred late with 75% of the failures occurring after 3 months and 50% occurring after 6 months.This is consistent with the current study where the complication rate is 16.66 % (10% non union and 6.6% delayed union) and one case of implant failure occured at the end of 8 months.In 2013, **Hoffmann et. al** , analyzed in a retrospective design distal femur fractures treated with LCP for the clinical outcomes and complications in 243 cases and found that 18 % developed nonunion and Eighty-three (74.8%) of the fractures healed after the index procedure. Twenty (18.0%) of the patients developed a Non Unoin (NU). Four of 20 (20%) resulted in a recalcitrant NU. They analyzed that Closed injuries had a higher tendency to heal after the index procedure than open injuries (p = 0.057). Closed and minimally open (Gustilo/Anderson types I and II) fractures healed at a significantly higher rate after the index procedure compared to type III open fractures (80.0% versus 61.3%, p = 0.041). and submuscular group had better outcomes than openly reduced cases.They concluded that despite modern fixation techniques, distal femoral fractures often result in persistent disability and worse clinical outcomes. Soft tissue management seems to be important. Submuscular plate insertion reduced the nonunion rate.The study contradicts some of the previous studies in terms of complications and union with proposed increased incidence of implant failure and nonunion with LCP , but also stated that multiple factors influence the results. The present study also showed better results than Hoffman et al. with 90% union results with less incidence of implant failure and overall complications. The better results in this study compared to the Hoffmann et al, study may be related to the difference that none of the cases in this study were open fractures leading to less amount of soft tissue trauma and decreased chances of infection. Also more number of cases in the index study were younger population with the mean age of 40 yrs as opposed to the Hoffmann et al study where more than 40 % cases were open fractures with mean age of 54 years which shows more percentage of osteoporotic bones due to older age group population.In the current study, 30 cases of distal femur fractures were studied with an average age of 40 years. The average union time was 16.6 weeks and is 15.6 weeks excluding the two cases of delayed union.10 % incidence of non-union, 3 % implant failure, 7% deep infection, 3% each of >5 degrees varus and valgus malalignment. there were two cases of delayed union. On analyzing it retrospectively the reason for delayed union would have been severe metaphyseal comminution both of which were treated with secondary bone grafting and protected partial weight bearing. Both the cases went on to union one at the end of 31 weeks and another at the end of 29 weeks.In the study, there were 3 cases of non-union, two of which was found to be due to infective non-union due to deep infection. They were managed with implant removal, wound debridement with application of local antibiotic beads and application of Ilizarov ring fixator . The other case was a case of comminuted supracondylar fracture Muller type C3, which went for screw breakage and implant failure. On analyzing it retrospectively we believe the cause for implant failure was shorter plate length (5,6 holed) and severe metaphyseal comminution which lead to gap non-union. The case is being planned for exchange plating with a longer plate with bone grafting. Normal knee flexion is 140 degree. Laubethal has demonstrated that average motion required for:

Normal sitting	93 degree
Stair climbing	100 degree
Squatting	117 degree

Thus, acceptable knee flexion compatible with daily activity would be around 110 degree. In this study, At a mean follow-up of 10 months, the mean knee flexion was 109 degrees. The average knee extensor lag was 2.4 degrees.Functional outcome at the end of 6 to 8 months was assessed using NEER's scoring system.

CRITERIA FOR EVALUATION OF THE RESULTS
(FROM NEER CS, II GRANTHAN SA, AND SHELTON ML)[15]

Functional (70 points)		Anatomical (30 points)	
a) *Pain (20 points)*		a) *Gross anatomy (15 points)*	
• No pain	20	• Thickening only	15
Intermittent	16	• 5 degree angulation or 0.5 cm shortening	12
• With fatigue	12	• 10 degree angulation or rotation. 2 cm shortening	9
• Limits function	8	• 15 degree angulation or rotation. 3 cm shortening	6
• Constant or at exertion	4-0	• Healed with considerable deformity	3
b) *Walking capacity (20 points)*		• Non-union or chronic infection	0
• Same as before accident	20	b) *Roentgenogram (15 points)*	
• Mild restriction	16	• Near normal	15
• Restricted stair side ways	12	• 5 degree angulation or 0.5 cm displacement	12

EXCELLENT: MORE THAN 85

GOOD: 70 TO 85 POINTS

FAIR : 55 TO 69 POINTS

POOR: LESS THAN 55

• Use crutches or other walking aids	4-0	• 10 degree angulation or 1 cm displacement	9
c) *Joint movement (20 points)*		• 15 degree angulation or 2 cm displacement	6
• Normal or 135 degrees	20	• Union but with greater deformity, spreading of condyles and osteoarthritis	3
• Up to 100 degrees	16	• Non-union or chronic infection	0
• Up to 80 degrees	12		
• up to 60 degrees	8		
• Up to 40 degrees	4		
• Up to 20 degrees	0		
d) *Work capacity (10 points)*			
• Same as before accident	10		
• Regular but with handicap	8		
• Alter work	6		
• Light work	4		
• No work	2-0		

Results were excellent in 17 patients (57%), good in 8 (27%), fair in 2(6%) and poor in 3(10%). In our studies functional results are close to the functional results achieved in other studies so are the rate of complications.*Limitations:* Limitations of our study are that the minimum follow up of 6 months is only enough to comment on healing and midterm functional results. It cannot be commented on the development of degenerative joint disease which would be interesting with such a high rate of intra-articular fractures (consisting of 60% of cases) in this study cohort.

- In this study, open injuries where LCP was used after primary debridement were not included. so, this cohort doesnot assess the functional outcome of LCP in cases with damage to soft tissues following open wounds.

- Another important determinant in the study is that most of the patients in this cohort are illiterates and daily labourers who cannot afford regular and proper physiotherapy following surgery which we believe, has a definite role in functional outcome.
- Finally, the study cohort is relatively small with only 30 cases meeting the inclusion criteria and hence further studies with multicentric large scale prospective studies are needed for further evaluation of outcomes.In this study, it has been observed that the operative technique respecting biologic and biomechanical principles does influence the success of treating these fractures with locking plates significantly . A Similar analysis has been shown in previous studies by Greiwe RM et. al and Erhardt JB et. al.With respect to biology, during the procedure, it is of utmost importance that the muscle and periosteal bone cover is preserved. In cases of comminution, free fragments must be left untouched. With a biological fixation technique and a fixed-angle implant, the periosteal blood flow remains intact and bone healing is less disturbed. With respect to biomechanical principles, emphasis should be to use long plates, to apply bicortical screws, to leave two to three screw holes empty around the fracture gap in simple fractures in order not to create a too rigid construct, and to position the screws adjacent to a comminuted fracture as close as possible to the fracture gap.

CONCLUSION

1. High incidence of distal femur fractures are seen in young patients with high velocity injuries and accidental falls in older patients showing a bimodal distribution.
2. The introduction of locking compression plates with option of locked screws has provided the means to increase the rigidity of fixation in osteoporotic bone or in the presence of periarticular fractures.
3. Traditionally the duration of surgery in distal femoral fractures has been high which had complications of high incidence of infections . While using LCP, the duration of surgery can be minimized (furthermore with the use of LISS and MIPPO methods) as there is less need for soft tissue dissection which can decrease the incidence of infection , amount of blood loss and complications of anasthesia
4. Early mobilization is possible as the system provides good angular stability and hence the incidence of post operative prolonged immobilization can be reduced and thus reducing the incidence of knee stiffness.
5. It has a greater advantage over other implants in case of osteoporotic bones where it has less incidence of screw cutout, late collapse and malalignments.
6. The results with open reduction are comparible with minimally invasive methods of fixation because in case of LCP, soft tissue dissection is not essential as it is an internal fixator and donot need plate bone contact to function.
7. Locking Compression Plate when used with minimally invasive methods, like the LISS or MIPPO would probably give better functional results as the soft tissue dissection is kept tp minimum
8. Thus, whatever is the technique of fixation, MIPPO or LISS or open method, and whatever is the adequacy of reduction, proper functional outcome depends on following of proper principles amount of intraoperative soft tissue dissected and post operative protocol followed in terms proper physiotherapy.
9. It must be remembered that careful intraoperative attention should be given to restoring alignment in all planes. Restoration both medial and lateral column necessary to prevent complication.
10. Potential reasons for implant failures include

- Technical errors in plate selection and placement,
- use of shorter plates in severe comminution as this makes the implant, a more rigid construct increasing chances of implant failure and reducing the possibility of beneficial micromotion at fracture site
- Early weight-bearing in the presence of delayed fracture union and hence close follow-up is needed specially in comminuted fractures and in cases of osteoporotic bones.

11. Judicious use of bone grafting may improve the outcome and union rates specially in cases of severe metaphyseal comminution.
12. The incidence of osteoarthritis is theoritically less with LCP as it is an angle stable implant compared to other implants and the current study with a followup of 6 to 18 months is not enough to comment upon, but the incidence will be less if the intraarticular restoration of condyles is acheived which is often difficult in case of severe intra articular comminution as the locking screw holes doesnot allow the surgeon to place the screws in different angles.
13. Further improvement in designs (like the polyaxial systems) and better understanding of the locking plate systems are needed for better results from these novel Internal fixators as we believe this is an excellent option in fixing distal femoral fractures specially so in osteoporotic and comminuted intraarticular fractures.

REFERENCES

1. Arneson TJ, Melton LJ 3rd, Lewallen DG, et al. Epidemiology of diaphyseal and distal femoral fractures in Rochester, Minnesota,1965-1984. Clin orthop. 1988;234:188-94
2. Schandelmaier P, Partenheimer A, Koenemann B, Grun OA, Krettek C. Distal Femoral Fractures and LISS Stabilization. *Injury*2001; 32: SC 55-63.
3. Martinet O, Cordey J, Harder Y, Maier A, Bühler M, Barraud GE. The epidemiology of fractures of the distal femur. Injury. 2000 Sep;31 Suppl 3:C62-3.
4. Michael Z, Mohit B, et al. Operative treatment of acute distal femur fractures: systematic review of 2 comparative studies and 45 case series (1989-2005). J Orthop Trauma 2006; 20:366-71.
5. Kregor PJ, Stannard J, Zlowodzki M, Cole PA, Alonso J. Distal femoral fracture fixation utilizing the Less Invasive Stabilization System (L.I.S.S.): The technique and early results. *Injury* 2001; 32: SC 32-47.
6. Schutz M, Muller M, Regazzoni P, et al. Use of the Less Invasive Stabilization System (LISS) in patients with distal femoral (AO33) fractures: a prospective multicenter study. Arch Orthop Trauma Surg 2005; 125(2): 102-8.
7. Giles JB, Delee JC, Heckman JD. Supracondylar-Intercondylar fractures of femur treated by supracondylar plate and lag screw. JBJS, 64-A, No. 6, pg. 864-70, 1982.
8. Hall MF. Two-Plane Fixation of acute supracondylar and intercondylar fractures of the femur. South Med J 1978; 71:1474.
9. Kregor PJ, Stannard JA, Zlowodzki M, et al. Treatment of distal femur fractures using the less invasive stabilization system: surgical experience and early clinical results in 103 fractures. J Orthop Trauma. 2004;18: 509-520.
10. Heather V, Theresa H, John S, et al. Failure of LCP condylar plate fixation in the distal part of the femur. J Bone Joint Surg 2006; 88-A: 846-53.
11. Hugh Owen Thomas. Quoted by Rockwood CA, Green DP. Fractures in adult, 4th ed, Vol. II, pg. 1972-1993, 1996.
12. Fritz Steinman. Quoted by Rockwood CA, Green DP. Fractures in adult, 4th ed, Vol. II, pg. 1972-93,1996.
13. James E Anderson. Grant's Atlas of Anatomy. 8th Edition, Anastomosis Around Knee, 4-54, 4-55; Knee Joint, 4-56, 4-57, 4-60.
14. Weil Kuenher, Henry.Quoted by Stewart MJ, Sisk TD, Wallace SL. Fractures of distal third of femur-compression method . JBJS,48-A, pg. 784-807, June 1966.
15. Tees. Quoted by Stewart MJ, Sisk TD, Wallace SL Fractures of distal third of femur - A compression method of treatment. JBJS, 48-A, pg. 784-807, June 1966.
16. Modlin. Quoted by Stewart MJ, Sisk TD, Wallace SL. Fractures of distal third of femur - a compression method of treatment. JBJS, 48-A, pg. 784-807, June 1966.
17. Umansky. Quoted by stewart MJ, Sisk TD, Wallace SL. Fractures of distal third of femur - A compression method of treatment. JBJS, 48-A, pg. 784-807, June 1966.
18. Hampton. Quoted by Stewart MJ, Sisk TD, Wallace SL Fractures of distal third of femur - A compression method of treatment. JBJS, 48-A, pg. 7840807, June 1966.
19. Wiggins. Quoted by Stewart MJ, Sisk TD, Wallace SL. Fractures of distal third of femur- A compression method of treatment. JBJS, 48-A, pg. 784-807, June 1966.
20. Wilson JN. Watson Jone's: Fractures and joint injuries. 6th ed, pg. 1003-070, 1982.
21. White and Russian. Quoted by Stewart MJ, Sisk TD, Wallace SL. Fractures of distal third of femur - A compression method of treatment. JBJS, 48-A, pg.784-807, June 1966.
22. Charnley John. The closed treatment of common fractures. 3rd ed, Pg. 197- 204.
23. Bank HH. Healing of intraarticular fractures. Clin Orthop, 40; Pg. 17-29, 1965.
24. Stewart MJ, Sisk TD, Wallace SL, Fractures of distal third of femur- A comparison methods of treatment. JBJS, Vol. 48-A, pg. 784-807, June 1966.
25. Neer CS, Gratham SA, Shelton ML et al Supracondylar fractures of adult femur. JBJS, Vol. 49-A, pg. 591-613, 1967.
26. Anderson Randolph. Conservative treatment of fractures of the femur. JBJS, Vol.49-A, No. 7, Pg. 1371-375, 1967.
27. Vert Mooney. Quoted by Wardlaw D, James Mclauchalan et al. Biomechanical studies of cast brace treatment of femoral shaft fractures. JBJS, Vol. 63-B, No. 1, pg. 7-11, 1981.
28. Olerud Sven. Operative treatment of supracondylar fractures of femur - Technique and results in 15 cases. JBJS, Vol. 54-A, No. 5, pg. 1014-032, July 1972.
29. Zickel RE, Fiette VG. A new fixation device for distal third of femur. Clin Orthop, 125, pg. 185-91, 1977.
30. Austin Brown, JC D'Arcy. Internal fixation for supracondylar fracture of femur in elderly patients. JBJS, Vol. 53-B, Pg. 420-24, 1970.
31. Riggins RS, Garrick JG, Lipscomb PR Supracondylar fractures of femur - Survey of treatment. Clin Orthop, B2, pg. 32-36, 1972.
32. Enneking WF, Marshall Horowitz. The intraarticular effect of immobilization on the human knee. JBJS, Vol. 54-A, No. 5, Pg. 973-85, July 1972.
33. Connoley JF, Paul King. Closed reduction and early cast brace ambulation in the treatment of femoral fractures. JBJS, Vol. 55-A, Pg. 1559-99, Dec 1973.
34. Pavel Alan, Smith RL. Prophylactic antibiotic in clean orthopaedic surgery. JBJS, No. 4 56-A: 777-82, June 1974.
35. Schatzker J, Horne G, Waddell J. The Toronto experience with supracondylar fractures of femur. Injury, 6, pg. 113-28, 1975.
36. Gustilo RB, Anderson JT. Prevention of infection in the treatment of 1025 open fractures of long bone. Retrospective and prospective analysis. JBJS, Vol. 58-A, pg. 453-58, June 1976.
37. Schatzker J, Lambert DC. Supracondylar fractures of femur. Clin Orthop, 138, pg. 77-93, 1979.
38. Zimmermann AJ. Intraarticular fractures of distal femur. OCNA, 10, pg. 75-80, 1979.
39. Wardlaw D, James McLauchlan et al. Biomechanical studies of cast brace treatment of femoral shaft fractures. JBJS, Vol. 63-B, No. 1, pg. 7-11, 1981.
40. Kolmert Lars, Jrister Wulff. Epidemiology and treatment of distal femoral fractures in adults. Acta Orthop Scand, 53, pg. 957-62, 1982.
41. Mize RD, Bucholz RE et al, Surgical treatment of displaced comminuted fracture of distal end of femur. JBJS, Vol. 64-A, No. 5, pg. 871-79, July 1982.
42. Schelbourne K Donald, Bruckmann FR. Rush pin fixation of supracondylar and intercondylar fractures of the femur. JBJS, Vol. 64-A, No. 2, Feb 1982.
43. Siliski JM, Mahring M, Hopir P. Supracondylar and intercondylar fractures of femur treated by internal fixation. JBJS, Vol. 70-A, No. 1, pg. 95-104, Jan 1989.

44. Shelton ML, Grantham SA, Ranbir Singh. A new fixation device for supracondylar and low femoral shaft fractures. J Trauma, 14, pg. 821-34, 1974.
45. Yang-Rong-Sen, Hwa-Chang Liv et al. Supracondylar fractures of the femur. J Trauma, Vol. 30, pg. 315-19, Mar 1990.
46. Sanders Roy, Swiontowski et al. Double plating of comminuted unsable fractures of distal part of femur. JBJS, Vol. 730, pg. 341-45, Mar 1991.
47. Leung KS, Shen WY, Mui LT. Interlocking intramedullary nailing for supracondylar and intercondylar fractures of distal part of femur. JBJS, Vol.73-A, pg. 332-40, Mar 1991.
48. Shewring DJ, Meggitt BF. Fractures of distal femur treated with AO dynamic condylar screw. JBJS, Vol. 74-B, No. 1, pg. 122-25, Jan 1992.
49. Lucas. Quoted by Rockwood CA, Green DP. Fractures in adult, 45h ed, Vol. II, pg.1972-93,1996.
50. Pemberton DJ, Evans PR. Supracondylar fractures of femur. Preliminary results of new fixation device. JBJS, Vol. 75-B, Supp. I, pg. 84, 1993.
51. Iannacone WM, Bennett FS, Delong WG Initial experience with the treatment of supracondylar femoral fractures using the supracondylar nail : A Preliminary Report. J Ortho Trauma, 8(4) : 322-7, Aug 1994.
52. Krickler SJ, Butt MS, Ali MS Displaced fractures of distal femur in the elderly patients. Operative vs non-operative treatment. JBJS, Vol. 78-B, No. 1, Jan 1996.
53. Danziger MB, Louci D, Zecher SB. Treatment of intercondylar and supracondylar distal femur fractures using the GSH supracondylar nail. Am J Orthop, 24 (9): 684-90, 1995.
54. Armstrong R, Milliren A, Schrantz W, Zeliger K. Retrograde interlocked intramedullary nailing of supracondylar distal femur fractures in an average 76-year-old patient population. Orthopedics. 2003;26(6):627–629.
55. Frigg R, Appenzeller A, Christensen R, Frenk A, Gilbert S, Schavan R. The development of the distal femur Less Invasive Stabilization System (LISS). *Injury* 2001; 32: SC 24-31.
56. Goesling T, Frenk A, Appenzeller A, et al. LISS PLT: design, mechanical and biomechanical characteristics. Injury. 2003;34:A11-A15.
57. Zlowodzki M, Williamson RS, Cole PA, et al. Biomechanical evaluation of the Less Invasive Stabilization System, angled blade plate, and retrograde intramedullary nail for the internal fixation of distal femur fractures. J Orthop Trauma. 2004;18:494-502.
58. M. Ahmad; R. Nanda; A.S. Bajwa; J. Candal-Couto; S. Green; and A.C. Hui; Biomechanical testing of locking compression plates: is distance between bone and implant significant? JBJS vol 88-B, Issue_III, 401
59. Egol, Kenneth A. MD; Kubiak, Erik N. MD; Fulkerson, Eric MD; Kummer, Frederick J. PhD; Koval, Kenneth J. Biomechanics of Locked Plates and Screws
60. Yeap, E.J., and Deepak, A.S., (2007) Distal Femoral Locking Compression Plate Fixation in Distal Femoral Fractures: Early Results. Malaysian Orthopaedic Journal , 1 (1). pp. 12-17. ISSN 1985 2533
61. Zlowodzki M, Bhandari M, Marek DJ, Cole PA, Kregor PJ. Operative treatment of acute distal femur fractures: systematic review of 2 comparative studies and 45 case series (1989 to 2005). J Orthop Trauma. 2006; 20(5):366- 371.
62. Markmiller M, Konrad G, Sudkamp N. Femur-LISS and distal femoral nail for fixation of distal femoral fractures: are there differences in outcome and complications? Clin Orthop Relat Res. 2004; (426):252-257.
63. Vallier HA, Hennessey TA, Sontich JK, Patterson BM. Failure of LCP condylar plate fixation in the distal part of the femur. A report of 6 cases. JBJS Am. 2006; 88(4):846-853.
64. Marti A, Fankhauser C, Frenk A, Cordey J, Gasser B. Biomechanical evaluation of the less invasive stabilization system for the internal fixation of distal femur fractures. J Orthop Trauma. 2001; 15(7):482-487.
64a .Zlowodzki M, Williamson S, Cole PA, Zardiackas LD, Kregor PJ. Biomechanical evaluation of the less invasive stabilization system, angled blade plate, and retrograde intramedullary nail for the internal fixation of distal femur fractures. J Orthop Trauma. 2004 Sep;18(8):494-502
65. Higgins TF, Pittman G, Hines J, Bachus KN. Biomechanical analysis of distal femur fracture fixation: fixed-angle screw-plate construct versus condylar blade plate. J Orthop Trauma. 2007; 21(1):43-46.
66. Ricci W, Zheng, Z, Jones, B, Cartner, J. Does Locked Plating Provide Improved Fatigue Properties over Nonlocked Plating and Does Bone Quality Matter? OTA Annual Meeting Poster Presentation Boston, MA; 2007.
67. Wilkens KJ, Curtiss S, Lee MA. Polyaxial locking plate fixation in distal femur fractures: a biomechanical comparison. J Orthop Trauma. 2008 Oct;22(9):624-8.
68. Krbec M, Motycka J, Lunácek L, Dousa P. [Osteosynthesis for periprosthetic supracondylar fracture above a total knee arthroplasty using a locking plate]. Acta Chir Orthop Traumatol Cech. 2009 Dec;76(6):473-8. Czech.
69. Freeman AL, Tornetta P 3rd, Schmidt A, Bechtold J, Ricci W, Fleming M. How much do locked screws add to the fixation of "hybrid" plate constructs in osteoporotic bone? J Orthop Trauma. 2010 Mar;24(3):163-9.
70. Grawe B, Le T, Williamson S, Archdeacon A, Zardiackas L. Fracture fixationwith two locking screws versus three non-locking screws: A biomechanical comparison in a normal and an osteoporotic bone model. Bone Joint Res. 2012 Jun1;1(6):118-24.
71. Hoffmann MF, Jones CB, Sietsema DL, Tornetta P 3rd, Koenig SJ. Clinical outcomes of locked plating of distal femoral fractures in a retrospective cohort. J Orthop Surg Res. 2013 Nov 27;8:43.
72. Ricci WM, Streubel PN, Morshed S, Collinge CA, Nork SE, Gardner MJ. Risk factors for failure of locked plate fixation of distal femur fractures: an analysis of 335 cases. J Orthop Trauma. 2014 Feb;28(2):83-9.
73. Weight M, Collinge C. Early results of the less invasive stabilization system for mechanically unstable fractures of the distal femur (AO/OTA types A2, A3, C2, and C3). J Orthop Trauma. 2004;18:503-508.
74. Henderson CE, Kuhl LL, Fitzpatrick DC, Marsh JL. Locking plates for distal femur fractures: is there a problem with fracture healing? J Orthop Trauma. 2011Feb;25 Suppl 1:S8-14. doi: 10.1097/BOT.0b013e3182070127.
75. Schütz M, Müller M, Krettek C, Höntzsch D, Regazzoni P, Ganz R, Haas N. Minimally invasive fracture stabilization of distal femoral fractures with theLISS: a prospective multicenter study. Results of a clinical study with special emphasis on difficult cases. Injury. 2001 Dec;32 Suppl 3:SC48-54.
76. Wong MK, Leung F, Chow SP. Treatment of Distal Femoral Fractures in the E l d e r l y Using a Less-Invasive Plating Technique. *IntOrthop* 2005; 29: 117-20.
77. Greiwe RM, Archdeacon MT. Locking plate technology: current concepts. J Knee Surg. 2007;20(1):50–5.
78. Erhardt JB, Grob K, Roderer G, Hoffmann A, Forster TN, Kuster MS. Treatment of periprosthetic femur fractures with the non-contact bridging plate: a new angular stable implant. Arch Orthop Trauma Surg. 2008;128(4):409–16.
79. Stoffel K, Dieter U, Stachowiak G, Gachter A, Kuster MS. Biomechanical testing of the LCP-- how can stability in locked internal fixators be controlled?. Injury. 2003;34 (Suppl 2):B11–9.