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Original Research Article

Study of functional outcome of tibial plateau fractures treated with anatomical contoured locking compression plate

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ABSTRACT

Background: Tibial plateau fractures tend to occur in patients with polytrauma and in elderly patients with history of significant fall. This study was undertaken to evaluate and explore new generation implant fixation in tibial plateau fractures which is expected to provide a stable fixation with minimum exposure, early mobilization, less complications and a better quality of life.

Materials and Methods: About 43 cases who had sustained tibial plateau fractures (Schatzker type I-VI) and operated with anatomical contoured locking compression plate were included. Follow-up of these patients was done at 6 weeks, 3 months, and 6 months after surgery. We analyzed all our subjects using IKDC score for functional outcome and plateau depression measurement for radiological outcome at 3 months and 6 months.

Results: All the 43 fractures analysed in this study were graded in accordance to the Schatzker classification. It was observed that most of these fractures, i.e., 16 out of 43 (37.2%) were type VI and 13 out of 43 (30.2%) type V. The average knee flexion at 3 months was 105.7±8.49 degrees and at 6 months 120.6±8.61 degrees. After evaluation, it was observed that at 6 months, 3 patients had extension lag (7%) out total 43 patients. Most of the patients had average IKDC score of 80.2±7.91% at 3 months which increased to average 86.92±8.05% at 6 months.

Conclusion: Achieving and maintaining anatomical reduction becomes easy with advanced design of these plates, which helps in early mobilization and hence obtaining good functional and radiological outcomes of tibial plateau fractures.

1. Introduction

The tibial plateau makes up the superior articular surface of the tibia constituting one of the most critical load-bearing areas in the human body.[1] Fractures of this region represent a wide spectrum of severity, which range from simple injuries with predictably excellent outcomes after non-operative treatment to complex fracture patterns that challenge even the most experienced surgeons. Complex biomechanics of its weight bearing position and complex ligamentous stability and articular congruency are the main reason why these fractures are of concern to surgeon.[2,3]

Tibial plateau fractures represent approximately 1% of fractures in adults. Most of these injuries (55-70%) affect lateral plateau. Isolated injuries to the medial plateau occur in 10-23% cases; whereas bicondylar fractures noted in 10-30% cases.[4] Tibia plateau fractures are result from a combination of axial loading with varus or valgus

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stress during flexion and extension movements.[5] Various classification systems are available for classifying these fractures including Schatzker classification system and AO classification. Classifying the fractures for the purposes of selecting optimal treatment is of increased importance. The Schatzker classification defines pathoanatomy in AP radiograph and suggests treatment strategies and this classification remains central to the language of tibia plateau fractures.[5,6] The Schatzker classification system for tibial plateau fractures, which divides these fractures into six types, is widely recognized by orthopaedic surgeons to assess the initial injury, plan management and predict a prognosis. Schatzker type IV, V and VI fractures are high-energy fractures often accompanied by other local and systemic injuries.[7]

In the current medical literature there is no consensus about the best approach to treat these fractures. The management of tibial plateau fracture has been controversial and the objective of stable, pain free knee joint with a good functional range of motion as well as good radiological restoration of tibial articular surface of knee joint eluded most of the management modalities.[8] Among the different options available, the surgical methods most commonly in use are plating, C.C. screws as treatment modalities for internal fixation and hybrid external fixation. Non-operative modalities like cast, braces or traction are complicated by intrinsic risks of poor functional results and extended hospital stay, whereas open reduction and stable internal fixation helps in maintaining the articular surface and restoration of the mechanical alignment which allows early mobilization of knee. Open reduction and internal fixation has its own complications.[9,10]

The development of anatomical contoured locking compression plates as an implant for internal fixation, has allowed us from total invasive to minimally invasive approaches. It is done often allowing single and dual plating with enhancement in the handling of soft tissue.[11,12] Proximal tibial anatomical contoured locking compression plate is based on biomechanical principle of external fixators and internal fixators, since the angle-stable interface between the screws and the plate allows placement of the plate without any contact to the bone giving the advantage of preserving the periosteal blood supply and bone perfusion.[11]

The purpose of this study is to evaluate the functional outcome by using international knee documentation committee score and radiological outcome by measuring tibial plateau depression on follow up of patients. We prospectively collected results of open reduction and internal fixation with anatomical contoured locking compression plates. The aim of study was functional & radiological outcomes of tibial plateau fractures treated with anatomical contoured locking compression plate.

2. Materials and Methods

2.1. Study site

Department of Orthopaedics at CMRI Hospitals, Kolkata, West Bengal.

2.2. Study population

Patients admitted in department of Orthopaedics at CMRI hospital, Kolkata for treatment of intra-articular fractures of proximal Tibia.

2.3. Study design

Observational, Prospective Study.

2.4. Sample size

43 patients admitted in CMRI hospital, Kolkata for intra-articular fractures of the proximal tibia from September 2017 – June 2018 were selected for this study. In this study n (sample size)= $z\alpha 2p(1-p)/e2$ where p is proportion, e is precision. Here α= 5% hence $z\alpha$ =1.96 p = 1% e = 3% n is coming as 43. Hence at least 43 patients have been taken for the study.

2.5. Inclusion criteria

1. Displaced and unstable tibial plateau fractures
2. Skeletally mature patients
3. Closed or Gustilo Anderson type 1 and type 2 open fracture
4. Operated within 3 weeks of injury

2.6. Exclusion criteria

1. Pathological fractures
2. Open fracture with extensive soft tissue damage where plate cannot be covered with soft tissue
3. Concomitant lower limb fractures like patella, femur, ankle and pelvic fractures
4. Extra articular fracture of proximal tibia

After obtaining approval from our institutional scientific and ethical committee followed by informed consent getting duly signed, 43 adult patients with tibial plateau fractures of any grade were included in the study following the inclusion and exclusion criteria. Different types of anatomical contoured locking compression plate for open reduction internal fixation of intra articular fracture of proximal tibia were used in the present study.

2.7. Preparation of the patient in operation theatre

Anaesthesia – All surgeries were performed under spinal anaesthesia except in case with head injury in which general anaesthesia was given.

Position - All the patients were operated in supine position with folded pillow under knee on a radiolucent fracture table. In all the patients a sponge pack was applied under the affected gluteal region in order to gain freedom in internal rotation of lower limb. The unaffected limb was kept in extended position. Pneumatic tourniquet was applied. The patient was prepared and draped, leaving the thigh exposed as required, for surgical incision and intra-operative evaluation of fracture alignment and image intensifier was positioned on the opposite side of the leg.

2.8. Surgical approaches

There are two frequently used surgical approaches to reduce and internally fix tibia plateau fractures, which are anterolateral approach and posteromedial approach. They are used in isolation for fractures of lateral and medial tibial plateau respectively. At present other approaches like anteromedial, posterolateral have becomes unusual or reserved for special circumstances to fix proximal tibia fracture fragments. Submeniscal incisions were given to expose the joint.

2.9. Anterolateral approach

The lateral condyle fracture was approached anterolaterally. "S" shaped incision was made starting 5 cm proximal to joint line curving the incision anteriorly over gerdy's tubercle and extend it distally 1cm lateral to anterior border of tibia. Fascial incision parallel to the anterior border of the iliotibial tract was be made. Underlying muscle was retracted laterally. Joint capsule was incised. Tibialis anterior was elevated by blunt dissection. [13]

2.10. Posteromedial approach

Through posteromedial approach to proximal tibia with approximately 6 cm incision over posteromedial border of proximal tibia after opening subcutaneous fat, the long saphenous vein and saphenous nerve were identified and preserved. Pes anserinus expansions were identified. Tibia was approached after incising pes anserinus longitudinally in the line of skin incision. The gastrocnemius muscle was gently freed from posteromedial surface by blunt dissection. It has got the advantage of relatively good soft tissue cover and it is widely separated from the antero-lateral approach allowing these two approaches to be combined when necessary. [13]

2.11. Surgical technique

Fracture reduction was done under C-arm guidance by closed methods using ligamentotaxis for intraarticular fracture extending to metaphysical region. Combined traction with valgus or varus strain was done in flexion or extension of knee as per the need of the individual case depending upon the reduction. Submeniscal arthrotomy was done for articular reduction under direct vision for severely depressed fractures. Compression bony clamp was used in cases to bring the fracture fragments together. Percutaneous K wires were used to hold the fragments in reduction. We typically fixed medial tibial condyle first. If medial condyle was comminuted then we fixed lateral condyle to achieve length.

The fragments were elevated and reduced, followed by temporary fixation with multiple small Kirschner wires in reduction position. If depression was present in articular surface, elevation followed by bone grafting using autologous bone graft or bone graft substitute was done. Anatomical contoured tibial locking plate for definitive fixation was then applied. Cortical screws (3.5/4.5mm) were used to attach the plate to the shaft of the tibia at distal most part. Then large locking head screws were inserted in the proximal part of the buttress plate, and the distal portion was completed with remaining cortical screws. The whole construct was checked under C-arm image intensifier, followed by closure of wound in layers.

2.12. Post-operative protocol

Well-padded sterile dressing was done. Knee was not immobilised. Post-operative X-ray were done to document proper reduction and fixation of fracture fragments. Antibiotics (Intravenous/Oral) were continued till the wound condition necessitated. Active knee mobilisation was encouraged as much as the patient could tolerate. Quadriceps exercises and ankle mobilization were started from 2^{nd} or 3^{rd} post operative day according to the tolerance of patients or associated injuries. Suture removal was done on 15^{th} post-operative day. Patient was discharged with non-weight bearing crutch walking. Progressive weight bearing was allowed according to the callus formation as assessed in follow up X Rays at 6 weeks.

2.13. Follow up

We assessed the patients clinically and radiologically at regular follow up in OPD with X-rays done at 6 weeks, 3 months, and 6 months. During follow up post-operative complications related to procedure like infection, wound break down, arthrofibrosis and angular deformity were recorded. The final result was based on the functional and radiological outcome at 3months and 6 months. A preference for data collection of follow-up was post-op visits up to 6 months. The results were compiled and analysed using international knee documentation committee (IKDC) score for functional recovery at knee joint and restoration of tibial articular surface by measuring plateau depression for radiological recovery after surgical intervention of fracture tibial plateau using anatomical contoured locking compression plate on final follow up at

6 months.

2.14. IKDC score measures

IKDC is a subjective scale that provides patients with an overall function score.[14] The questionnaire looks at 3 categories: symptoms, sports activity, and knee function. The symptoms subscale helps to evaluate things such as pain, stiffness, swelling and giving-way of the knee. Meanwhile, the sports activity subscale focuses on functions like going up and down the stairs, rising from a chair, squatting and jumping. Scores are obtained by summing the individual items, then transforming the crude total to a scaled number that ranges from 0 to 100. This final number is interpreted as a measure of function with higher scores representing higher levels of function and lower levels of symptoms.[14]

2.15. Statistical analysis

Categorical variables will be expressed as number of patients and percentage of patients and compared across groups using Pearson's Chi Square test for Independence of Attributes and Fisher's Exact Test as appropriate. Continuous variables will be expressed as Mean ± Standard Deviation and compared across groups using unpaired t test/One Way ANOVA if the data follows normal distribution and Mann-Whitney U test/Kruskal Wallis Test if the data does not follow normal distribution. The statistical software SPSS version 20 will be used for the analysis. An alpha level of 5% has been taken, i.e. if any p value is less than 0.05 it will be considered as significant.

3. Results

This was a prospective study to evaluate tibial plateau fractures managed with anatomical contoured locking compression plates. The study included 43 cases of fracture of tibial plateau presenting to the emergency and outpatient department of CMRI Hospital, Kolkata from 23rd September 2017 till 31st June 2018.

3.1. Age incidence

It was observed in study, that fractures of tibial plateau were more common in younger (55.8%) and middle aged (30.2%) population with higher incidence in third and fourth decade. The age group of 31-40 years is perhaps the most productive period of one's life (Table 1). These severe injuries during this age are bound to have a negative effect on the life of this age group. Hence there is need for appropriate treatment of these injuries.

3.2. Gender distribution

Of the 43 patients analyzed 36 were males (83.7%) and 7 were females (16.3%). Road traffic accident was the

Fig. 1: Preoperative image: Clinical

Fig. 2: Preoperative image: Preoperative X-ray AP/LAT view

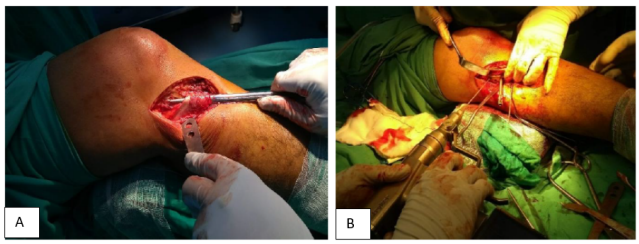

Fig. 3: Intraoperative images: **A:** Posteromedial approach; **B:** Posteromedial plating

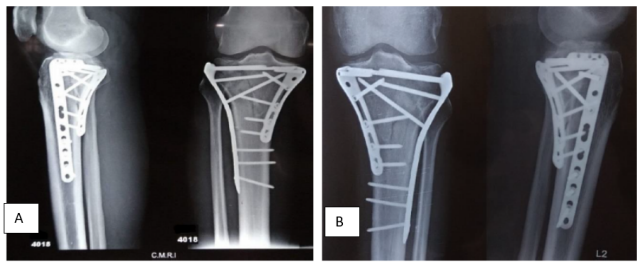

Fig. 4: A: Immediate postoperative X-ray; **B:** At 6 weeks follow up X-ray

Fig. 5: A: Flexion at 6 months; **B:** Extension at 6 months

Table 1: Age & sex distribution of subjects

Age	Frequency	Percent
21-30	2	4.7
31-40	24	55.8
41-50	13	30.2
51-60	3	7.0
61-70	1	2.3
Sex		
Female	7	16.3
Male	36	83.7
Total	43	100

common cause of fracture in all of these patients. The males being involved in outdoor activities in Indian settings makes them prone to vehicular accidents and hence the higher incidence of fractures was observed in them.

Table 2: Mode of injury [MOI] and side affected distribution

MOI	Frequency	Percent
Fall	5	11.6
RTA	38	88.4
Side		
Left	28	65.1
Right	15	34.9
Total	43	100.0

3.3. Mode of injury

The nature of injury was high velocity injury in 38 cases (88.4%) as it is explained by all patients sustaining road traffic accident. 5 (11.6%) cases had sustained injury as a result of trivial trauma and domestic fall as occurs in elderly with osteoporotic bone (Table 2).

3.4. Side of injury

Among the 43 patients analysed in this study, 28patients (65.1%) had left sided injury in tibia plateau fractures. The remaining 15 patients (34.9) had right sided tibial plateau fracture. In this study left side tibial plateau fracture was common being an important finding.

3.5. Classification of fracture (grade)

All the 43 fractures analysed in this study were graded in accordance to the Schatzker classification. It was observed that most of these fractures, i.e. 16 out of 43 cases (37.2%) were type VI and 13 out of 43 cases (30.2%) type V. The next common being other types in that 6 out of 43 cases (13.9%) were for type II and 5 out of 43 cases (11.6%) type III fractures, 2 out of 43 cases (4.7%) type IV and 1 out of 43 cases (2.3%) type I. This signified that majority of fractures in this study had severely comminuted intraarticular fractures and the cases we selected were all displaced and unstable fractures (Figure 6).

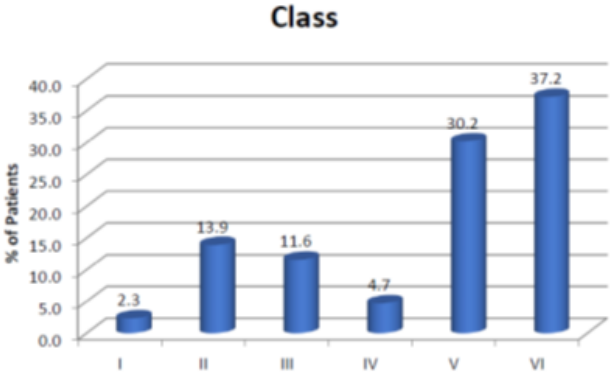

Fig. 6: Distribution of subjects according to class

3.6. Injury to operation interval (time of surgery)

The average period from day of injury to surgery was 3±0.98 days with a range between 3 to 7 days (Table 3).

Table 3: Injury operation interval

	Mean	Median	Std. Deviation
Injury-operation interval	3.74	3.00	0.98

3.7. Flexion of Knee joint

The average knee flexion at 3 months was 105.7±8.49 degree and at 6 months 120.6±8.61 degree. 14 patients

with single plate fixation showed movement more than 29 patients with dual plate due to less intraoperative soft tissue strip off. In our study it's noted that in all patients flexion of knee was gradually improved at 6 months. The reason for fair range of motion in 8 patients was poor adherence to physiotherapy and late weight bearing and in 2 patients due to stiffness caused by infection. (Table 4).

Table 4: Distribution of subject according to flexion movement at 3 and 6 months

	Mean	Median	Std. Deviation
Knee flexion (Degree) - 3 Months	105.70	110.00	8.49
Knee flexion (Degree) - 6 Months	120.58	120.00	8.61
p Value		<0.001	
Significance		Significant	

3.8. Extension lag at knee

After evaluation, at 3 months extension lag of <10 degree was observed in 4 patients (9.3%). It was improved in 1 patient at 6 months, remaining 3 patients with extension lag (7.0%) out total 43 patients. Another important finding was that extension lag was more common in type VI fractures (Table 5).

3.9. Pain during activity

In our study, we observed that pain during mild and moderate activity gradually improved to pain on moderate or strenuous activity and no pain from 3 to 6 month follow up. Thirty five (35) patients out of 43 had no pain on final follow up. We also noted that pain in type V and VI with dual plate fixation on strenuous activity at 6 months (20.69%) is more than type I to IV with single plate fixation (7.14%) (Table 6).

3.10. Stair climbing

In our study stair climbing was impaired in 8 patients out of 43 (18.6%) at 3 months, which was improved to become 1 patient out of 43 (2.3%) at 6 months. In this case of impaired stair climbing was due to painful knee stiffness (Table 7).

3.11. Squatting

It was observed in our study of 43 subjects, that at 3 months squatting was impaired in 32 patients (74.42%), which were improved at 6 months follow up showing impaired in 17 patients (39.53%). In the study it's also signified that majority of patients with impaired squatting out of 17 at 6 months follow up were Type V 3(23.08%) and VI 11(68.75%) fractures (Table 8).

3.12. IKDC score

In our study, most of the patients average IKDC score was 80.2±7.91% at 3 months which was increased to average 86.92±8.05% at 6 months. Higher IKDC score is suggestive of higher level of functional outcome with lower level of symptoms. Another remarkable finding was in all patients mid-term follow up was good according to IKDC score which included symptoms, sports activity, and knee function (Table 9).

4. Discussion

4.1. Age and sex incidence

In this study of 43 subjects, it was observed that displaced and unstable fractures of tibia plateau were more prevalent in younger and middle aged population. The mean age being 44.86 years in unicondylar plateau fractures and 38.45 years in complex bicondylar plateau fractures (range 30-70 years). Males were more commonly affected than females (36 males and 7 females). In the study by Lee et al. (2007),[15] the mean age of the patients was 42 years (range 18 - 82 years). There were 23 male patients and 12 females. The mean age of the patients was 42 years (range 19-83) in the study by Stannard et al. (2004).[16] There were 25 males and 12 females in the same study. In another study by Schutz et al. (2003),[17] the patients included 6 women and 16 men aged between 22 and 59 years (mean age of 42 years).

In a study by Sangwan et al. reported from North India (2002)[8] the average age of the patients was 35.5 years (range 21-50 years) with male to female ratio of 11.5: 1. Hence, proximal tibial fractures were seen in younger and middle aged population. Since this age group is involved in more outdoor activities in the Indian setting, so they are more prone for injury especially due to vehicular accidents.[16,18,19]

4.2. Mode of injury

In our study, we noted 5 out of 43 patients had domestic and accidental fall. Another 38 out of 43 patients suffered such fractures after high velocity road traffic accidents (88.4% of cases). In the study by Rademakers et al. (2007)[20] motor vehicle crash was the most common mechanism of injury present in 78% of cases. In the study by Lee et al. (2006),[15] the cause of the injury was an auto-versus- pedestrian accident in 17 patients, a motor vehicle accident in 11 patients, a fall in 4 patients, a blow in 2 and a shotgun injury in 1 patient. In the study by Stannard (2004),[16] patients sustained their fractures by the following mechanisms: motor vehicle accident;[21] fall;[11] motor vehicle versus pedestrian;[13] crush injury;[1] and airplane crash.[1] In the study by Sangwan et al. (2002),[9]

Table 5: Distribution of subject according to knee extension lag at final follow up 6 months

		Class						Total	p Value	Significance
		I	II	III	IV	V	VI			
Knee extension lag (Degree) - 6 Months	<10	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (18.75)	3 (6.98)	0.480	Not Significant
	None	1 (100)	6 (100)	5 (100)	2 (100)	13 (100)	13 (81.25)	40 (93.02)		
Total		1 (100)	6 (100)	5 (100)	2 (100)	13 (100)	16 (100)	43 (100)		

Table 6: Distribution of subject had pain during activity at final follow up 6 months

		Class						Total	p Value	Significance
		I	II	III	IV	V	VI			
Pain during activity - 6 Months	None	1 (100)	6 (100)	3 (60)	2 (100)	11 (84.62)	12 (75)	35 (81.4)	0.545	Not Significant
	Moderate	0 (0)	0 (0)	1 (20)	0 (0)	0 (0)	0 (0)	1 (2.33)		
	Strenuous	0 (0)	0 (0)	1 (20)	0 (0)	2 (15.38)	4 (25)	7 (16.28)		
Total	1 (100)	6 (100)	5 (100)	2 (100)	13 (100)	16 (100)	43 (100)	Total		

Table 7: Distribution of subject according to Stair climbing at final follow up 6 months

		Class						Total	p Value	Significance
		I	II	III	IV	V	VI			
Stair climbing - 6 Months	Impaired	0 (0)	0 (0)	1 (20)	0 (0)	0 (0)	0 (0)	1 (2.33)	0.186	Not Significant
	Normal	1 (100)	6 (100)	4 (80)	2 (100)	13 (100)	16 (100)	42 (97.67)		
Total	1(100)	6 (100)	5 (100)	2 (100)	13 (100)	16 (100)	43 (100)	1 (100)		

Table 8: Distribution of subject according to squatting at final follow up 6 months

		Class						Total	p Value	Significance
		I	II	III	IV	V	VI			
Squatting - 6 Months	Impaired	0 (0)	1 (16.67)	2 (40)	0 (0)	3 (23.08)	11 (68.75)	17 (39.53)	0.061	Not Significant
	Normal	1 (100)	5 (83.33)	3 (60)	2 (100)	10 (76.92)	5 (31.25)	26 (60.47)		
Total		1 (100)	6 (100)	5 (100)	2 (100)	13 (100)	16 (100)	43 (100)		

Table 9: Distribution of subject according to IKDC score at 3 and 6 months

	Mean	Median	Std. Deviation
IKDC score - 3 Months	80.20	83.90	7.91
IKDC score - 6 Months	86.92	90.80	8.05
p-value		<0.001	
Significance		Significant	

traffic accidents was the mechanism of injury in 21 patients while hit by an animal in 2 patients, fall in 1 patient and sport injury in 1 patient. Thus, proximal tibial fractures are more common after high energy trauma especially motor vehicular and bike accidents.

4.3. Fracture class and type

All the 43 fractures analysed in this study were graded in accordance to the Schatzker classification. We have met with all displaced and unstable fractures in that 1 type I fractures, 5 as type II, 5 as type III gross intra-articular lateral depression considered as it makes fracture configuration and joint unstable, commonly associated with meniscal trapping, 2 type IV fractures, 13 type V fractures and 16 type VI fractures. In the study by Sangwan et al. (2002),[9] the fractures were graded using the criteria of Schatzker et al as type I in 9 patients, type II in 1 patient, type IV in 5 patients, type V in 2 patients and type VI in 8 patients. In another study by Rademakers et al. (2007),[20] 70 patients had fracture of the lateral condyle (Schatzker

I/II/III) and 7 had fracture of medial condyle (Schatzker IV). Fourteen (14%) had Schatzker type VI fracture.

In the study of functional recovery by Gaston P et al. (2007)[21] reported the incidence of tibial plateau fracture according to Shatzker grading: 9 had type I, 23 had type II, 12 had type III, 11 had type IV, 3 had type V and 5 had type VI. This signified that majority of fractures in the study had severely comminuted intra-articular fractures. Higher grade of these fractures was attributed to high velocity trauma and low velocity trauma in osteoporotic bones even with low grade makes fracture unstable.[22–24]

In our study out of 43 fractures, 8 fractures (18.6%) were open fractures and remaining 35 were closed fractures (81.4%). Open fractures indicate the severity of trauma associated with tibia plateau fractures. We have selected only Gustilo Anderson type 1 and 2 fractures. These are less severe soft tissue injury where after wound care internal fixation is sound option. We recorded that 7 out of 8 open fractures seen were type V and type VI fractures which is again suggestive towards high velocity of trauma mostly in RTA cases.

4.4. Injury operation interval

The timing of surgery depended on the soft-tissue conditions. In our study of 43 fractures all underwent open reduction internal fixation within 3 weeks of injury. The average period from day of injury to surgery was 3 and half days in range of minimum 3 days to maximum 7 days.

In study by Xu YQ et al. (2013),[25] wound complication incidences were 20.0%, 41.6%, 33.3%, 2.5%, and 16.7% within 4 hours, 4 hours to 3 days, 3-5 days, 5-8 days, and more than 8 days after injury respectively. They conclude optimal surgical timing is within 4 hours after trauma, for which no obvious swelling was observed in the limbs. This is followed by surgical timing within 5-8 days, after which trauma showed only subsided limb swelling.

Girish H. et al. (2017),[26] conducted study of 32 cases of tibial plateau fractures with applying internal fixation system since injury within 4 hours of injury or 1 week after the injury, when the swelling and the inflammatory reactions have subsided. They noted only 3 cases of postoperative wound complication and infections. Final result in our study recorded that, there was no immediate postoperative wound complication in any patients after 3 and half day of injury operation interval. We have found out that swelling and soft tissue tension reduced after 3 and half day from injury.

4.5. Knee flexion

In our study of 43 subjects average postoperative knee flexion at 3 months was 105.7 degree and at 6 months 120.58 degree, as we looking towards functional outcome which is acceptable to do daily activities. 8 patients (18.6%) developed knee stiffness at 6 months. In all cases knee movements was gradually improved from 3 to 6 months during which patient was on continuous physiotherapy of knee joint. We have used low profile implants, which can be fixed with open, MIPO, small incision reduction technique according to fracture configuration and soft tissue condition of fractured limb. Single plate fixation shows better range of motion then dual plate fixation. We reported that these advanced plates developed less periarticular adhesion as compared to conventional plates because they required less intraoperative soft tissue strip off. In the study by Lee et al. (2007),[15] the overall knee range of motion averaged 105 degree at the latest follow-up.

In the study by Stannard et al. (2004),[16] knee motion ranged from a mean of 1degree (range 0-10degree) to 127degree (range 90 -145 degree). In the study by Schutz et al. (2003),[17] the range of motion was 0-105 degree. In three cases after complete healing, a restriction averaging 85 degree was observed at the knee joint. An extension deficit of 10 degree was observed in one case. The study concluded that proximal tibia LISS system ensured stable fixation until healing when applied for the treatment of proximal tibial fractures. In another study by Egol et al. (2004),[27] at latest follow-up, the mean knee extension was 1° (0–15°) and the mean knee flexion was 109.3° (60–135°).

Thus, proximal tibial anatomical contoured locking compression plate is a good low profile device to stabilize the fractures of proximal tibia especially when used in conjunction with meticulous intra operative handling of soft tissues and active participation of the patients in rehabilitation programme.[27,28] In summary, anatomical contoured locking compression plate is an efficient bone stabilization device even in cases with soft tissue injuries. Lack of flexion motion in some cases was thought to result from damage to the extensor retinaculum, to the joint surface or surgical exposure for fixation or to both. Extensor mechanism scarring with or without arthrofibrosis of the knee or patellofemoral joint can lead to restricted knee movement.[29,30]

4.6. Knee extension lag

In our study of 43 patients, we reported postoperative knee extension lag of <10 degree in 4 patients (9.3%) at 3 months and 3 patients (7.0%) at 6 months follow up. We also noted another finding, that was all 4 patients of knee extension lag was with knee stiffness and at 6 months 1 patients extension lag was improved and remained in 3 patients (7.0%). We hypothesized that knee extension lag was due to periarticular adhesion and irregular physiotherapy protocol and also it was more common with dual plating in type V and type VI fractures.

In the study of functional recovery by Gaston P et al. (2007),[21] they analysed 63 patients. 51 patients treated with ORIF, 5 type VI fractures were treated by minimal internal fixation augmented with external fixation and 7

patients treated non operatively. Fifty-two patients (82%) had >100 degree knee flexion and 39 (62%) had an extension deficit of <5 degree at three months. The findings of this study indicate that quadriceps function is impaired for a considerable period following a fracture of the tibial plateau. They also found that only 14% of patients achieved normal quadriceps muscle strength at one year, while only 30% had restoration of normal hamstring muscle strength at this time.

In study of S Prabhakar et al. (2018),[31] they observed 21 patients (100%). They reported none of the patients had extension lag at 6 months. In study of 63 subjects by Nirav Kumar Moradiya et al. (2016),[32] 38 were managed by MIPPO reduction, 25 were managed by ORIF. They reported average mean loss of extension: 7.20° (Range 5-20°). Hence, therefore it is better to advised, in patients with a complex fracture of the tibial plateau that there is risk of arthrofibrosis with knee extension lag if quadriceps exercises and postoperative rehabilitation are not followed.

4.7. Stair climbing

In present study, we reported stair climbing was impaired in 8 patients (18.6%) at 3 months which gradually improved over rehabilitation program at 6 months with only 1 patient (2.3%) with impaired stair climbing. We reported 97.7% of patients had no difficulty at all in stair climbing at final follow up. In our study patient with impaired stair climbing had arthrofibrosis and pain during moderate activity.

In study done by S Prabhakar et al. (2018),[31] they used Honkonen Jarvinen Criteria (1992) scoring system to measure functional outcome. In study of 21 patient they found only 1 patient (4.8%) having difficulty in stair climbing. Dhrubajyoti Talukdar et al. (2016)[33] assessed functional outcomes in ten months using the knee society score in 51 patient of complex and unstable tibial plateau fractures. They reported impaired stair climbing, 14 patients had slight to moderate difficulty, 5 patients showed very severe difficulty while 2 patients could not do their standard and functional activities because of restriction of movement of knee joint.

In a study conducted by Mohammad Ali Tahririan et al. (2014),[34] they reported functional outcome in 20 cases treated with locking plates and 21 cases treated with non-locking plates. In this study functional outcomes in ten months were assessed using the Knee Society knee score that considers a functional score (that assesses walking distance and stair climbing, daily activities). In this study the mean of functional score was also higher in the locking plate group than in the nonlocking plate group at the follow-up (77.26 ± 9.95 versus 69.55 ± 10.22, $P = 0.026$). Hence, our study and the described study shows after using anatomical configured locking plates, the stair climbing function is not hampered in majority of postoperative patients at midterm and long term follow up.

4.8. Squatting

Among 43 patients we assessed squatting was impaired in 32 patients (74.4%) at 3 months showing significant majority of case but at midterm follow up at 6 months finally, impaired in17 cases (39.5%). All patients improved due to adherence to physiotherapy. In final follow up, we also noted that impaired squatting was more common among patients operated with dual plating for complex intraarticular tibial plateau fractures. In study done by S Prabhakar et al. (2018),[31] they used Honkonen Jarvinen Criteria (1992) scoring system to measure functional outcome. In study of 21 patients they found 8 patients (38.1%) having difficulty in squatting due to pain.

Dhrubajyoti Talukdar et al. (2016)[33] assessed functional outcomes in ten months using the knee society score in 51 patient of complex and unstable tibial plateau fractures. They reported impaired squatting with,14 patients had slight to moderate difficulty, 5 patients showed very severe difficulty while 2 patients could not do their standard and functional activities because of restriction of movement of knee joint.

In study conducted by Mohammad Ali Tahririan et al. (2014),[34] they reported functional outcome in 20 cases treated with locking plates and 21 cases treated with nonlocking plates. In his study, functional outcomes in ten months were assessed using the Knee Society knee score that considers a functional score (that assesses walking distance and stair climbing, daily activities). In this study the mean of functional score was also higher in the locking plate group than in the nonlocking plate group at the follow-up (77.26 ± 9.95 versus 69.55 ± 10.22, $P = 0.026$).

Hence, the residual knee stiffness and pain during extreme flexion was responsible for impaired squatting function in postoperative patients on midterm follow up. Another thing hypothesised here is patients with impaired squatting had poor adherence to the postoperative rehabilitation protocol.

4.9. IKDC score

In present study we analysed our 43 patients of displaced and unstable tibial plateau fracture with international knee documentation committee score. IKDC score detect improvement or deterioration in symptoms, function, and sports activities due to knee impairment.[14,35] The International Knee Documentation Committee Subjective Knee Form provided the reliable overall measure of symptoms and disabilities that are most important to this traumatic cartilage repair patients.[36]

Among 43 patients we reported mean IKDC score at 3 months 80.2%±7.91% and at 6 months 86.92%±8.05%. Another important finding was at 6 months final follow up, mean IKDC score was higher (89.59%) in unicondylar plateau fractures with single plate fixation and 85.63% in

bicondylar plateau fractures with dual plate fixation. We hypothesised IKDC score had correlation with severity of trauma and type of fixation.

Mohammad Ali Tahririan et al. (2014)[34] in their clinical study comparing the functional outcomes of tibial plateau fractures treated with nonlocking and locking plate fixation by knee society score, found a score of 80.2 for locking plate and 72.5 for non-locking plate. Average range of knee flexion was found to be 122.3 degrees for locking plate and 115.7 degrees for non-locking plate. In our study, locking plate was used for all the cases. Average knee society score was found to be 92.5 and average knee flexion was found to be 120.9 degrees. So, functional outcome in our study was marginally better than the locking plate group in that study and significantly better than the non-locking group. This shows the superiority of the locking plate in view of stable fixation and early range of motion when compared to non-locking plate.

Chang-Wug Oh et al. (2006)[37] in their study on double plating of 23 subjects with type V and type VI proximal tibial fractures using minimally invasive percutaneous osteosynthesis found 18 patients with excellent, 3 patients with good and 2 patients with fair results. Average rasmuseen score was found to be 26 and average knee range of motion was found to be 123 degrees.

In study of dual plating done by S Prabhakar et al. (2018),[31] they used Honkonen Jarvinen Criteria (1992) scoring system. Clinical outcome noted was 81% excellent, 16.6% good and 2.4% fair. The functional outcome was 71.3% excellent, 19.1% good, 6.7% fair and 1.9% poor. Thus, in accordance with the described study postoperative functional outcome in form of scoring suggest the all patient underwent surgery with this novel anatomical locking implants shows better postoperative functions and lower level of the symptoms.

5. Conclusion

This was a prospective study to evaluate displaced and unstable tibial plateau fractures managed with anatomical contoured locking compression plates. In our study fractures of tibial plateau were more prevalent in younger and middle-aged population with male dominance. Left side involved in 65.1% and right side involved in 34.9%. All the fractures analyzed in this study were graded in accordance to the Schatzker classification. It was observed that most of these fractures i.e., 16 out of 43 (37.2%) were type VI and 13 out of 43(30.2%) type V. At final follow up we reported out of 43 cases 18.6% case having residual pain during activities and among these majorities of patient had pain on strenuous activities only. About 81.4% had no difficulty in any activities.

The advent and development of anatomical contoured locking compression plates has effectively improved tibial plateau fractures fixation method. It is commonly seen, that most of the intraarticular proximal tibia fractures in developing countries are due to be RTA, which tends to be displaced and unstable fractures. At the same time surgical treatment options for the same are also being modified continuously.

Achieving and maintaining anatomical reduction becomes easy with advanced design of these plates with less soft tissue dissection. So it helps in early mobilization and hence obtaining good functional and radiological outcomes of tibial plateau fractures. For rehabilitation following fixation there is no substitute for early physiotherapy.

6. Source of Funding

None.

7. Conflict of Interest

The authors declare no conflict of interest.

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