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Dr. Amit N Rajpal
Resident, Department of Orthopaedics Peerless Hospital & B. K. Roy Research Centre, Kolkata, West Bengal, India

Dr. Ayon Das
Senior Resident, Department of Orthopaedics, IPGMER & SSKM Hospital, Kolkata, West Bengal, India

Dr. Arijit Das
RMO Cum Clinical Tutor, Department of Orthopaedics, IPGMER & SSKM Hospital, Kolkata, West Bengal, India

Corresponding Author:
Dr. Ayon Das
Senior Resident, Department of Orthopaedics, IPGMER & SSKM Hospital, Kolkata, West Bengal, India

Intra-articular bicondylar tibial plateau fractures managed surgically by dual plate osteosynthesis: A clinico-radiological and functional outcome evaluation

Dr. Amit N Rajpal, Dr. Ayon Das and Dr. Arijit Das

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Abstract
Background: The management of bicondylar fracture of proximal tibia is a challenging task and the objective of treatment is to achieve stable, painless and mobile joint and also to prevent the secondary degeneration of the joint. Dual plating in such fractures is beneficial to address fracture fragments in different planes and also to achieve anatomical reduction under direct vision. The aim of the study was to evaluate the functional results in patients with tibial plateau bicondylar fracture treated by open reduction and internal fixation using dual plate osteosynthesis.
Materials and Methods: Patients who underwent dual plate fixation for post-traumatic bicondylar tibial plateau fracture were included in the study. This was a prospective study conducted at a Tertiary care Private Hospital in Kolkata, between August 2017 to May 2020. All patients were followed up at an interval of 2 weeks, 6 weeks, 12 weeks, 6 months, 9 months, 1 year and 1.5 year. Radiological and functional results were classified in four categories as per Rasmussen's criteria.
Results: Outcome at final follow-up was assessed with Rasmussen's functional grading system. In a total of 40 patients, 24 (60%) patients showed Excellent and 11 (27.5%) patients had Good results whereas 4 (10%) patients had Fair outcome and 1 (2.5%) patient demonstrated Poor surgical result at the final follow-up. Rasmussen's radiological assessment showed 7 (17.5%) Excellent, 25 (62.5%) Good, 5 (12.5%) Fair and 3 (7.5%) patients with Poor result. At the end of 1.5 year, the average Rasmussen's functional knee score for 40 patients was 25.85 ± 4.83.
Conclusion: Dual plate fixation of intra-articular bicondylar tibial plateau fractures is a safe and effective treatment option as it provides good surgical exposure, less soft tissue injury, rigid fixation, acceptable alignment of articular congruity, reasonable time to union and allows early weight bearing and range of motion of knee with good functional outcome.

Keywords: tibial plateau, proximal tibia, bicondylar fracture, dual plate fixation, Rasmussen's criteria

Introduction
Tibial plateau fractures account for 1 to 2% of all fractures and approximately 8% of fractures in the elderly. They have a bimodal distribution, affecting elderly over 60 years due to trivial fall on ground and young adults with high velocity injury involving road traffic trauma or fall from height [1].
Most of the tibial surface is subcutaneous throughout its length and hence, open fractures are more common in the tibia than in any other major long bones. Furthermore, the blood supply to tibia is more precarious than that of bone enclosed by heavy muscles [2]. Complex biomechanics of its weight bearing position along with variegated ligamentous stability and articular congruency are the main reason why these fractures are of concern to surgeon.
The majority of proximal tibial and plateau fractures are secondary to high velocity trauma, where fracture results from direct axial compression along with a valgus (more common) or varus strain and indirect shear forces [3].
Serious intra-articular damage and soft tissue injury or inappropriate treatment can lead to post-operative complications such as infection, skin necrosis, malunion, deformity, and arthrosis in tibial plateau fractures [4-6]. The aim of surgical treatment of proximal tibia fractures is to restore congruent articular surfaces of the tibial condyles maintaining the mechanical axis and restoring ligamentous stability eventually so as to achieve functional

painless and good range of motion in the knee joint [7].

Bicondylar tibial plateau fractures are treated with techniques that stabilize both the medial and lateral columns, to reconstruct the articular surface and prevent varus collapse resulting from medial column failure. These fractures have intricate injury pattern with compromised soft tissue envelope which lead to unpleasant prognosis with significant morbidity.

Surgical fixation of bicondylar tibial plateau fracture is complicated because of metaphyseal and articular comminution and the frequent occurrence of associated soft tissue injuries. Current treatment options for complex bicondylar tibial plateau fractures consists of using various modalities which include fine wire fixators like Ilizarov circular fixator or Taylor spatial frame, external fixators, hybrid external fixators, dual column plating and more recently arthroscopically assisted reduction and internal fixation with plating [8-10].

Various treatment methods have been described by various authors, each with its own merits and demerits.[11] Though the ideal fixation method still remains controversial, double buttress plating technique gains the greatest popularity because of its advantages in diminishing the risks of articular incongruence, malalignment of mechanical load axis, and post-traumatic degenerative joint disease hence allowing early mobilization of the knee joint [12].

Dual plating via two incisions i.e., anterolateral and anteromedial/posteromedial has received support from many authors because it allow direct visualisation of the articular reduction with less amount of soft tissue stripping and complications [13, 14]. Though this method is not without its own demerits like skin necrosis and infection, still this method is an excellent management technique by proper selection of patients, adequate preoperative soft tissue healing time and careful raising of skin flaps during surgery [15].

The objective of this study was to represent our experience comprising cases of intra-articular bicondylar tibial plateau fracture which were treated by open reduction and internal fixation using dual plating to see whether the technique achieves acceptable reduction, stable fixation with minimum soft tissue damage and if this technique achieves favorable radiological union along with improved clinical and functional outcome.

Materials and Methods

This study was performed in accordance with the ethical standards of the institutional review board. 40 patients with post-traumatic intra-articular bicondylar tibial plateau fracture which were treated by dual plating osteosynthesis in the Department of Orthopaedics, Peerless Hospital and B. K. Roy Research Centre, Kolkata from August 2017 to May 2020 and fulfilling the inclusion criteria were considered in this study.

Inclusion criteria

- Skeletally mature patients above 18 years of age
- Closed injury
- Fresh fracture (<2 weeks old)
- Soft tissue injury of Oestern and Tscherne grade 0, I or II

Exclusion criteria

- Open wound
- Any other bone fracture of ipsilateral lower limb
- Pathological fractures due to metastasis, benign tumors or metabolic bone disorders
- Associated neurovascular injury or compartment syndrome
- Patients with polytrauma or head injuries that definitely influence rehabilitation

Operative Procedure

All cases of bicondylar tibial plateau fractures on presentation were initially treated by resuscitation and temporary stabilization of fracture by application of above knee slab and elevation over a Bohler-Braun splint. Associated injuries and medical comorbidities were documented. The neurovascular status of the affected limb, compartment syndrome and any blisters or open wounds was noted. Definitive fixation was employed only after clinical signs of soft tissue recovery appeared which included decreased swelling, healing of blisters and wrinkling of the skin around the proximal tibia.

The patients were subjected to a thorough history, clinical examination and pre-operative routine laboratory investigations, which was supplemented by radiographs in antero-posterior and lateral view of the knee joint along with a CT scan with 3D reconstruction.

All the patients were operated under spinal anaesthesia. Patients were positioned supine on a radiolucent operating table and a sandbag was kept under ipsilateral gluteal region in order to prevent external rotation of the lower limb. Pneumatic tourniquet was used in all cases. Medial column was fixed first followed by the lateral column in order to prevent varus collapse.

For medial column, depending on fracture anatomy, the plate was placed either anteromedially or posteromedially. For anteromedial fragment, a medial longitudinal incision to the knee was performed. Pes anserinus was partially detached, and a limited dissection of the medial collateral ligament was performed. After the capsule had been opened, medial meniscus uplift was performed in order to obtain an evaluation of the medial joint plate. Fracture reduction and temporary K-wire fixation was done. Then, a ‘T’ or ‘L’ buttress plate or a locking compression medial proximal tibial plate was used to fix the fragment. C-arm was utilized to position the plate below the level of the joint line and the plate was then fixed to the bone with appropriate screws. For posteromedial fragment, medial Lobenhoffer approach was used and the procedure was done in prone position. Inverted ‘L’ incision was given over posteromedial aspect of knee. An interval between gastrocnemius and pes anserinus was developed and fracture apex was visualised. The reduction manoeuvre involved extension of knee with a valgus force along with direct manipulation of fracture fragment. A small fragment plate either in buttress or antiglide mode was then placed to stabilize the fracture.

For lateral column, an anterolateral approach to the knee was performed. A curvilinear longitudinal incision was made starting from the lateral femoral epicondyle and passing over the Gerdy's tubercle and running parallel to the shin and 1 cm lateral to it. The iliotibial band was elevated from the Gerdy's tubercle and the underlying capsule. The tibialis anterior was elevated subperiosteally to expose the lateral surface of the lateral tibial condyle and shaft. Articular surface depressions were elevated by lifting it through just beneath the depressed fragment using a bone lever and the resultant metaphyseal void filled with autogenous cancellous bone graft from iliac crest wherever necessary. The meniscus was preserved or repaired whenever possible. An anatomical lateral tibial locking plate was used to fix the lateral column.

Implant positions were confirmed through fluoroscopy. Surgical wound was closed in layers over an in-situ suction drain. Sterile dressings were applied to the surgical incisions and a long knee immobilizer was applied.

Rehabilitation
Postoperatively, the patients were put in a long knee brace for 2 weeks. Ankle pumps, isometric quadriceps exercises and knee range of motion was encouraged from second day. Initially patients were allowed only non-weight bearing crutch/walker walking upto 6 weeks. Partial toe touch weight bearing using crutch/walker was started after 6 weeks and full weight bearing at the end of 12 weeks or after clinical and radiological union of the fracture.

Follow-up
The patients were regularly followed up for 1.5 year (2 weeks, 6 weeks, 12 weeks, 6 months, 9 months, 1 year and 1.5 year) for clinical as well as radiological evaluation. Except for the first visit, in which only range of motion and local wound condition was addressed, subsequent visits included thorough clinical and radiological assessment. Functional assessment of the patients was done at the final follow-up as per the Rasmussen Functional Knee Score.

Statistical analysis
The data was collected in Microsoft Excel (Windows 10; version 2016) and statistical software SPSS version 20 was used. Procedure of the data analysis was transcription, preliminary data inspection, content analysis and interpretation. Continuous variables like limp, pain, swelling etc. measurements were expressed as Mean ± Standard deviation and intergroup comparison done by one sample t-test at 0.05 level of significance. The categorical variables like age, sex, side, co-morbidity was expressed as number of patients and the variable significant level was identified using Pearson's Chi Square test at 0.05 level of significance.

Results

Age Distribution
The mean age in this study was 42.23 years. The youngest patient was 25 years old and the eldest patient was 60 years old. Overall, 80% patients were between the age group of 20-50 years. It might be because younger peoples are more active and involved in outdoor and sports activities which makes them more prone to injuries.

Table 1: Age Distribution

Age (years)	No. of Patients	Percentage (%)	P value
21-30	6	15.0	0.799
31-40	11	27.5	
41-50	15	37.5	
51-60	8	20.0	
Total	40	100.0	

Sex Distribution
33 patients (82.5%) were male and 7 patients were female (17.5%). Majority of patients were Male which may be because of more outdoor and sports related activities makes them more vulnerable to accidents and trauma.

Side of Injury Distribution
Number of Right knee involvement was 27 (67.5%) which was higher in comparison with Left knee involvement which was 13 (32.5%).

Mode of Injury Distribution
27 (67.5%) were involved in Road traffic accident, 8 (20%) patients suffered a fall, and 5 (12.5%) sustained trauma during sports activities.

Fracture type Distribution
The proximal tibia fractures were selected and classified as per the Schatzker classification and CT based 3-column classification system.

Table 2: Schatzker classification Distribution

Schatzker Type	No. of patients	Percentage (%)
V	12	30
VI	28	70
Total	40	100.0

As per CT based 3-column classification, anterolateral column involvement was found in all 40 patients, anteromedial column in 32 patients and posterior column was involved in 16 patients.

Additional Surgical Procedure
6 (15%) patients required cortico-cancellous bone grafting harvested from ipsilateral iliac crest to elevate the depressed bone fragments.

Interval between injury and surgery
The mean interval between injury and surgery was 4.23 ± 3.02 days (p value 0.043).

Duration of Hospital stay
The mean duration of hospital stay was 8.33 ± 2.85 days.

Time to radiological union
The average time to union as seen in radiographs was found to be 17 ± 2.72 weeks (p value 0.049). In almost 50% of cases fracture united in 14-16 weeks.

Subjective Complains
Pain

Table 3: Pain Incidence

Pain	No. of Patients	Percentage (%)	P value
Nil	23	57.5	0.001
Minimal	12	30	
Occasional ache	4	10	
At rest	1	2.5	
Total	40	100.0	

Walking capacity

Table 4: Walking capacity Incidence

Walking capacity	No. of Patients	Percentage (%)	P value
Normal	32	80	0.001
At least 1 hour	5	12.5	
Outdoor for 15 mins	2	5	
Indoor only	1	2.5	
Wheelchair/Bedridden	0	0	
Total	40	100.0	

Clinical signs
Extension:

Table 5: Extension Incidence

Extension	No. of Patients	Percentage (%)	P value
Normal	24	60	0.001
Lack of extension (0-10^0)	12	30	
Lack of extension (>10^0)	4	10	
Total	40	100.0	

Range of Motion

Table 6: Range of Motion Incidence

Range of Motion	No. of Patients	Percentage (%)	P value
Normal	28	70	0.001
75% of normal	6	15	
>50% of normal	4	10	
<50% of normal	2	5	
Total	40	100.0	

Stability

Table 7: Stability Incidence

Stability	No. of Patients	Percentage (%)	P value
Normal	34	85	0.001
Minimal instability	4	10	
Instability in flexion	1	2.5	
Instability in extension	1	2.5	
Total	40	100.0	

Rasmussen's Radiological Assessment
As per the radiological criteria, there were 7 (17.5%) patients with Excellent result, 25 (62.5%) with Good, 5 (12.5%) with Fair while 3 (7.5%) patients with Poor result.

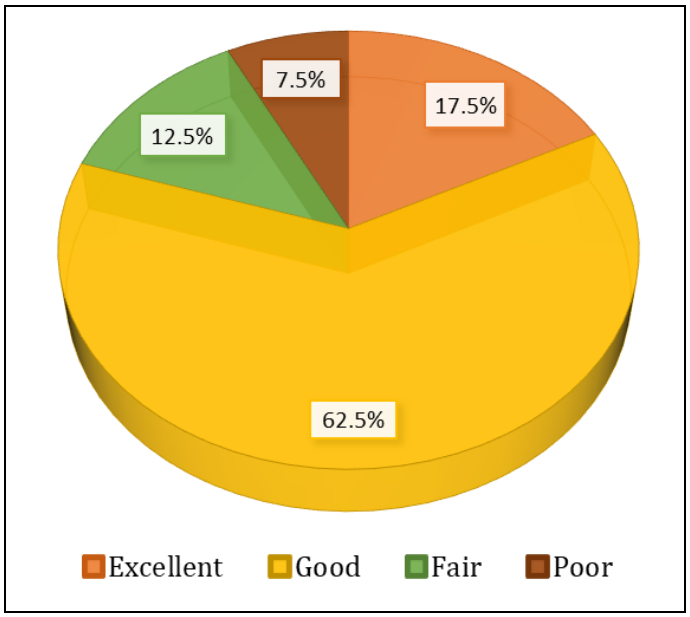

Fig 1: Rasmussen's Radiological Assessment

Rasmussen's Functional Knee Score
At the end of 1.5 year, the average Rasmussen Functional Knee score for 40 patients was 25.85 ± 4.83.

Rasmussen's Functional Outcome
In a total of 40 patients, 24 (60%) patients showed Excellent and 11 (27.5%) patients had Good results whereas 4 (10%) patients had Fair outcome and 1 (2.5%) patient demonstrated Poor surgical result at the end of 1.5 year final follow-up.

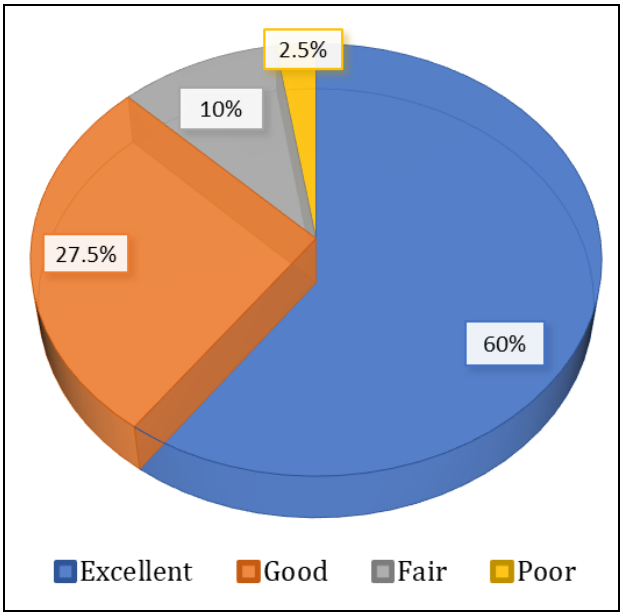

Table 2: Rasmussen's Functional Outcome

Complications
In a total of 40 patients, 34 patients (85%) did not have complication.
Infection was observed in 2 cases (5%). The infection was superficial in one case and deep in the other. Superficial infection was managed by intravenous antibiotics for 2 weeks given as per the culture and sensitivity report. Second patient that developed deep infection required surgical debridement and addition of antibiotic coated bone cement beads. Following this, the infection subsided and implant removal was not required. This patient developed knee stiffness with <50% of normal range of motion. Radiological union of fracture in this patient was observed at 22 weeks.
Another 1 patient (2.5%) that developed knee stiffness had significant swelling and blisters of knee and leg. Surgery was postponed for 7 days. After swelling subsided and wrinkle sign appeared, the patient was taken up for definitive fixation. Due to incongruity at articular surface, this patient developed 10^0 fixed flexion deformity and knee stiffness with ROM >50% of normal. Radiological union of fracture was observed at 20 weeks.
In 1 (2.5%) of the cases, the fracture healed with a mild malalignment (varus angulation of 10^0), but the patient did not complain of any significant functional instability.
1 patient (2.5%) had implant prominence on the medial side which was managed by debridement and secondary suture followed by dressing at regular interval.
Majority of patients (92.5%), presented within 1 week of injury. No major intraoperative complications such as excessive bleeding, iatrogenic fracture or neurovascular damage were encountered during the surgical procedure. Postoperative complications like skin necrosis, compartment syndrome or wound dehiscence were not seen any of the patients. No patient had to undergo implant removal for hardware related problems. Post-traumatic arthritis or nonunion was not found in any of the patients.

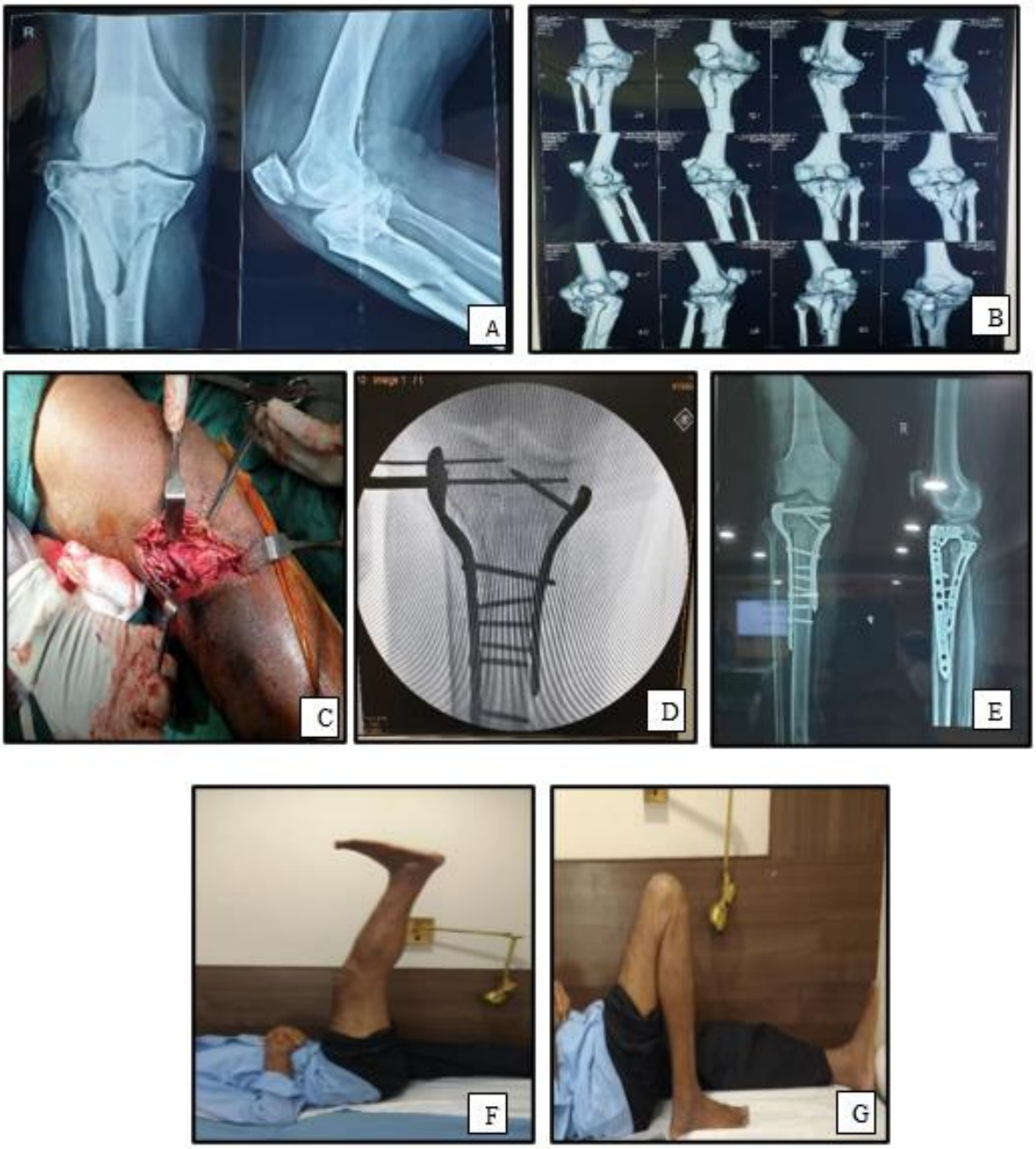

Fig 3: (A) Pre-op X-ray showing an intra-articular bicondylar tibial plateau fracture; **(B)** 3D reconstruction CT scan of the tibial plateau fracture; **(C)** Intra-op anterolateral approach to the knee; **(D)** Intra-op fluoroscopic view showing fracture reduction and plate placement with appropriate screw combination; **(E)** Immediate post-op X-ray; **(F)** Knee extension at final follow-up; **(G)** Knee flexion at final follow-up

Discussion

The results of complex bicondylar tibial plateau fractures are frequently overshadowed by devastating complications. High energy trauma and associated soft tissue injury increases the chances of complications. Surgery itself acts as a second hit to the soft tissues if not done at appropriate time. Therefore, optimal decision for the management of complex bicondylar tibial plateau fractures (Schatzker type V and VI) is of utmost importance.

The most common difficulties are faced by the surgeon while dealing with intra-articular proximal tibial fractures are the compromised skin and soft tissue envelope, which invites a high rate of complications following attempted open reduction and internal fixation, and poor bone quality and comminuted fracture patterns creating difficulty in achieving stable fixation [16, 17] Optimal timing for surgery, surgical time, soft tissue protection, and prevention of infection in tibial plateau fractures are important factors [18].

The goals of operative treatment for the tibial plateau fractures include anatomic reduction with restoration of articular congruity and rigid fixation for recovery of previous range of motion [4, 19, 20]. In all bicondylar tibial plateau fractures, a single lateral locking plate repair may not provide sufficient stability. Biomechanical and cadaver studies have shown that the dual locking plate fixation technique in bicondylar tibial plateau fractures allows less collapse when compared with the lateral locking plate fixation technique [21, 22].

Benefits of early mobilization gives better results in terms of good range of motion, less stiffness and quick articular healing. However, these benefits have to be balanced against complications which can be associated with early loss of reduction in severely comminuted fractures, extensive internal soft tissue insult, associated ligament injuries and other associated fractures involving ipsilateral limb. In these cases,

giving significant amount of time for soft tissue healing may benefit to reduce the surgical wound related problems as well as help in better compliance to the post-operative rehabilitation programme.

Although soft tissue complications and damage to the periosteal blood supply are major concerns in this method of internal fixation, [23, 24] the advantages of dual plating over other types of fixations include - coronal split of the medial condyle can be fixed separately with posteromedial plate, better reconstruction of articular surfaces, better distribution of forces along the axis of the bone, better load sharing capability with dual plates compared to single lateral plate alone. Also dual plates resist displacement, medial condyle collapse and allow early mobilization of the knee joint [11, 15, 25, 26].

The column theory of proximal tibia fracture plays an important role in pre-operative planning and fixation strategy. CT scan helps to reveal clear cut delineation and understanding of fracture pattern. It helps to demonstrate whether the apex is anterolateral or anteromedial or posterolateral or posteromedial and treat accordingly. In flexion type of injury posterior condyle is injured more whereas in extension type anterior part is involved more and in combined injury, any column might be injured.

In this study, our results demonstrate a lower risk for deep infection and soft tissue complications, good functional and bony results in complex proximal tibial fractures managed by dual plating when compared to earlier reports about other techniques. Studies have demonstrated that articular incongruity and joint instability can lead to early post-traumatic joint degeneration. The incidence of osteoarthritis following tibial plateau fractures is 17-83% [19, 27]. Since the follow-up period in this study was relatively short, so it might need more time to analyze the impact of this fracture episode to post-traumatic arthritis. Nonunion of bicondylar tibial plateau fractures has an incidence of approximately 4% [13, 28]. Nutrient vascular injury, bone defect, and lack of adequate fixation can cause this complication. There was no nonunion in our study, which might be related to the preservation of blood circulation of tissues during surgery. A spongious bone defect can easily occur in the tibial plateau fractures. The bone graft does protect the mechanical support and prevent late collapse [27, 29]. In our study, bone graft was used in 6 (15%) patients.

The main strategy of fixation is neutralization of fracture fragment. The depressed part should be elevated by either under direct supervision through submeniscus dissection or by indirect means under C-arm guidance to maintain intra-articular congruity. The plate is then applied over the apex of fracture to neutralize the shear force. In order to obtain stability of bicondylar and complex proximal tibial fractures, anatomical reduction and rigid fixation of both medial and lateral columns is necessary. Dual plating successfully gives a good stability by buttressing both columns and has equipollent rate of complications.

Limitations of our study include single institution bias, small group of patients, short follow-up period and a lack of Control group. Additional prospective and biomechanics studies should be conducted to confirm these outcomes in the future. A multicentre study with more patients is essential to substantiate benefits of this treatment method.

Conclusion

Open reduction and internal fixation of complex bicondylar tibial plateau fractures via dual plating using dual incisions provides good surgical exposure, minimal soft tissue compromise, adequate fixation, reasonable amount of stability, acceptable alignment of articular congruity and reasonable time to union. The biomechanical stability provided with dual plate fixation allows early range of motion with early weight bearing and helps in achieving good clinical and functional results. The post-operative complications can be reduced by proper timing of surgery, good soft tissue care intra-operatively and post-operatively. This procedure, in judiciously selected cases, allows early aggressive knee mobilization that in turn enhances the process of union, avoids knee stiffness and goes a long way in ensuring optimal functional recovery and patient satisfaction.

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