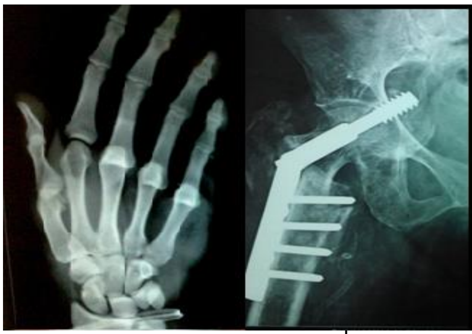

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The short term outcome with the use of modular external fixator in the management of bicondylar tibial plateau fractures

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Abstract
Background: Tibial plateau fractures (TPF) are critical due to their occurrence in a major weight-bearing joint, often resulting in significant functional impairment and complications. As one of the most common types of intra-articular injuries, these fractures present unique challenges in management. The objective of this study was to assess and compare the functional outcomes of internal fixation (IF) versus external fixation (EF) for the management of bicondylar TPF, with management approaches determined based on specific patient selection criteria.
Methods: A total of 60 cases with tibial condyle fractures (Schatzker type V and VI) were enrolled. Among these, 38 cases (with closed fractures or Type I and II open fractures with good skin conditions) underwent open reduction and IF (ORIF) using dual buttress plates, buttress plates, and CC screws. The remaining 22 cases (with closed fractures, Type I and II open fractures with poor skin conditions, or impending compartment syndrome (ICS)) were treated with hybrid EF. All cases were followed up at six weeks, six months, and twelve months to evaluate their functional outcomes using the Hospital for Special Surgery Knee-rating Score (HSSNRS) system.
Result: In our study, >85% of cases achieved good to excellent results according to the HSSNRS. At the 1-year follow-up, there was no significant difference in the functional outcomes between the two fixation methods. The average HSS score at the final follow-up was 78.87±10.94 for the IF group and 78.71±9.05 for the EF group.
Conclusion: Both IF and EF for bicondylar TPF can result in favorable functional outcomes, provided that the selection criteria are strictly adhered to. Careful case selection based on fracture type, soft tissue (ST) condition, and other factors is crucial to ensuring optimal results and minimizing complications. When applied appropriately, both methods offer effective solutions for restoring joint stability and function.

Keywords: Internal fixation, external fixation, tibial plateau fractures, dual buttress plate, non-union fracture

Introduction

TPF are significant due to their involvement in a major weight-bearing joint, often leading to severe functional impairment and complications [1]. These fractures are among the most common intra-articular injuries, accounting for 1.2% of all fractures. The high-energy forms, such as the bicondylar (Schatzker type V) and comminuted fractures (Schatzker type VI), present a considerable challenge to orthopedic surgeons worldwide [2, 3].

The pattern and severity of these fractures depend on factors like the case's age, bone quality, and the force applied to the proximal tibia [4]. Bicondylar fractures commonly involve articular depression, multiple displaced condylar fractures, meta-diaphyseal extensions, and comminution, often accompanied by injuries to the meniscus, ACL, and ST [5, 6]. Schatzker type VI fractures are especially associated with compartment syndrome (in around 30% of cases) and can also present as open fractures [7]. Complications like infection (8.4%-18%), malunion, wound breakdown, nonunion, joint instability, and post-traumatic arthritis are also common [8].

The energy from the injury is absorbed by the thin ST over the subcutaneous proximal tibia, causing significant ST damage [9, 10]. This necessitates careful surgical management to address the bony injury while preventing complications. The combination of high-energy fracture patterns and ST involvement contributes to the poor outcomes seen with both surgical and non-surgical managements [11, 12].

The main aims of treating high-energy TPF are to restore joint stability, maintain articular congruity, and ensure proper alignment, all while minimizing ST dissection and allowing for early knee mobilization [3, 13]. This approach aims to reduce known complications. Management options include using dual buttress plates, CC screws, locking compression plates, hybrid dual plates (a combination of locking and buttress plates), tubular external fixators, and hybrid EF. IF may be combined with tensioned wires in some cases [14, 15]. Various surgical approaches are used for open reduction and fixation, such as anterior midline, medial-lateral, and posterior incisions [16]. "Early motion" is often emphasized as a key factor in improving functional recovery from major intra-articular injuries [3].

This study compares the functional outcomes and complications of Schatzker V and VI TPF treated with IF using dual plates via an anterior midline incision versus EF using hybrid EF.

Methods

A prospective study was carried out between Mar 2023 to Jun 2025 at our 350-bed orthopedic clinic. It included cases over the age of 18 who presented with tibial condyle fractures categorized as Type V and Type VI according to the Schatzker classification [17]. Cases who were younger than 18, had fractures classified as Type I, II, III, or IV, vascular injuries, had pathological fractures, fractures associated with active infections, or ICS were excluded from the study.

A total of 60 cases were enrolled in the study, comprising 38 cases treated with IF (IF) and 22 cases treated with EF. All cases were followed up for a minimum of 12 months. The cases were assessed postoperatively for both functional and radiological outcomes at each follow-up visit.

Criteria for IF

- Absence of ICS
- Type 2 open fractures with intact skin
- Type 1 open fractures with intact skin
- Closed fractures with intact skin

Criteria for EF

- Closed fractures with blisters or poor skin condition
- Type 1 and 2 open fractures (blisters or poor skin condition)
- Type 3 open fractures
- Fractures plus ICS requiring fasciotomy

Preoperative evaluation included anteroposterior (AP) and lateral radiographs of the knee, supplemented by computed tomography (CT) scans to determine the fracture configuration, degree and site of articular depression, and any diaphyseal extension. Fractures were categorized based on Schatzker's classification [17], while associated soft-tissue injuries were graded according to the Gustilo Anderson system for open fractures [18]. Prophylactic intravenous antibiotics were administered before tourniquet inflation in cases of closed fractures.

Operative Procedure

All procedures were carried out under regional anesthesia with the patient positioned supine on a radiolucent operating table. A sandbag was placed beneath the ipsilateral gluteal region to achieve proper limb alignment. The iliac crest, designated for bone graft harvesting, was prepared and draped separately. A pneumatic tourniquet was applied for each surgery. Preoperative marking included identification of the patella, patellar tendon, tibial tuberosity, and both medial and lateral joint lines.

IF

A longitudinal anterior incision was made just lateral to the tibial crest, beginning at the lower border of the patella and extending distally in line with the fracture configuration. Full-thickness skin flaps were elevated bilaterally, revealing the subcutaneous tissue and underlying deep fascia. The aponeurosis covering the tibialis anterior muscle was split longitudinally, and the muscle was reflected subperiosteally to expose the lateral tibial condyle and adjacent shaft.

Fracture reduction was accomplished through a combination of direct and indirect maneuvers. Depressed fragments were elevated under fluoroscopic control by creating a cortical window on the anteromedial side and using a bone tamp. Fine adjustments and correction of any fragment tilt were performed with percutaneous K-wires, which also served for temporary fixation after satisfactory elevation. In cases with metaphyseal bone loss, an autologous iliac crest bone graft was used to fill the defect.

Definitive fixation was achieved using 6.5 mm cannulated cancellous lag screws typically two or three placed either independently or through the plate under fluoroscopic (C-arm) guidance. Metaphyseal stabilization was reinforced with buttress plating, utilizing a 4.5 mm "T" plate on the medial condyle and a 4.5 mm "L" plate on the lateral condyle. Following fixation, the wound was thoroughly irrigated and closed in layers over a suction drain, employing Vicryl sutures for the subcutaneous tissue and skin staples for the surface. Postoperatively, an above-knee plaster slab was applied for immobilization.

Postoperative (PO) radiographs were reviewed to assess articular reduction and alignment. The knee was immobilized for 3-4 weeks, after which knee movements were encouraged to prevent stiffness. Non-weight-bearing mobilization with crutches or a walking frame and quadriceps exercises began on PO day one. Partial weight-bearing was allowed at 12 weeks, with full weight-bearing starting at 16-20 weeks. Final follow-up X-rays were taken for cases treated with IF, and knee flexion and extension were assessed.

EF

For depressed articular fragments, a window is made, and the fragments are elevated using a bone tamp. Manual longitudinal traction and valgus force are applied to reduce the fragments. Once reduction is achieved, a clamp to hold the position is using, and a K-wire is inserted across the fracture.

To achieve stabilization of the articular surface, 6.5 mm cannulated screws are inserted parallel to the joint line within the subchondral region, crossing the primary fracture planes in a lag screw manner. Once the joint surface has been anatomically reduced, a hybrid external fixator is applied to maintain alignment between the metaphysis and diaphysis. The frame is constructed using one or two rings depending on the extent of the fracture with a clearance of approximately 3-4 cm around the limb. Posterior support is maintained with sterile sponges or towels to prevent posterior sagging of the leg.

Thin wires are inserted through the proximal tibia within the

designated safe zone, approximately 1 cm below the joint line to prevent intra-articular entry. The initial wire is placed horizontally from the lateral to medial side, positioned anteriorly and just above the fibular head. A second wire is then introduced from the posteromedial aspect toward the anterolateral surface. If needed, a third wire may be directed from the fibular head toward the antero-medial cortex. All wires are positioned under fluoroscopic guidance, maintaining an inter-wire angle of approximately 30-60 degrees.
The rings are assembled and tensioned, with all bolts tightened for stability. Additional Schanz pins are inserted for further support. The ring assembly is then connected to a uni-planar construct using 4.5 mm Schanz pins placed 3-4 cm apart on the antero-medial tibia, with connecting rods and pin clamps. If compartment syndrome is suspected, a fasciotomy is performed with incisions on the posteromedial and anterolateral aspects of the leg, and the wound is left open with sterile dressing. A split skin graft is done 2 days later.
Mobilization without weight-bearing using a walking frame, along with quadriceps strengthening and knee range of motion exercises, is initiated on the first postoperative day. After approximately 12 weeks, partial weight-bearing is permitted, progressing to full weight-bearing between 16 and 20 weeks. The external fixator is typically removed at 10-12 weeks, followed by the application of a cast.
Postoperatively, antibiotic coverage was administered for 5-7 days. Cases were encouraged to perform active digital movements and elevate the limb for preventing toes swelling. The first wounds inspection was done 24 hours post-surgery, and cases were discharged on the 2nd or 3rd PO day. Sutures were removed at 3 weeks. Follow-up visits were scheduled at 2, 6, 12 weeks, and monthly until bony union and maximal functional recovery to monitor fracture healing and knee joint movement.
Cases who met the selection criteria were called for follow-up at 6 weeks, 6 months, and 12 months. They were interviewed and examined for functional recovery using a standardized scoring system, and their responses were recorded. Findings were analyzed using the Hospital for Special Surgery knee-rating score (HSSKRS) system and compared statistically across follow-up periods. During each visit, cases were asked about knee pain, need for walking assistance, and varus or valgus stability examination, motion range, strength of quadriceps, lags extension, and deformities.
Statistical analysis was conducted using the Mann-Whitney U test. Data were described using SPSS ver. 24-software, with a $p<0.05$ considered significant.

Results

In our study, 60 cases were categorized in regard to the Schatzker-classification system. Of these, 54 cases (90%) had closed fractures, while 6 cases (10%) had open fractures. For Schatzker Type V fractures, 20 cases (33.3%) had closed fractures, and 2 cases (3.3%) had open fractures, classified as Type II (Gustilo-Anderson). In contrast, for Schatzker Type VI fractures, 34 cases (56.7%) had closed fractures, while 4 cases (6.7%) had open fractures, classified as Types I, II, or III. (Table 1)

Table 1: Fracture distribution according to type Schatzker type

Schatzker type	Closed fractures	Open fractures (Gustilo-Anderson)	Total
V	20 (33.3)	2 (II) (3.3)	22 (36.6)
VI	34 (56.7)	4 (I, II, III) (6.7)	38 (63.4)
Total	54 (90)	6 (10)	60

All cases underwent operations at a mean interval of 1-3 days. Emergency procedures were performed in 6 cases. Nine cases presented with preoperative ICS, for whom hybrid EF with primary fasciotomy was performed. PO radiographs (AP and lateral views) were taken to confirm articular reduction and the restoration of meta-diaphyseal alignment. All cases were followed up at 6 weeks, 6 months, and 12 months.
Functional outcomes were evaluated using the Hospital for Special Surgery Knee-Rating Scale (HSSKRS), (Table 2). At the final follow-up, 86% of cases achieved excellent to good results. A statistically significant difference was found in the HSSKRS are shown for both internal and EF groups. For IF, 5 cases (with scores between 85-100) had a mean score of 91±2.74, 13 cases (70-84) had a mean score of 77.31±3.95, and 3 cases (60-69) had a mean score of 64.33±3.22. No cases had scores below 60. For EF, 9 cases (85-100) had a mean score of 92.33±2.5, 24 cases (70-84) had a mean score of 77.88±4.42, 3 cases (60-69) had a mean score of 65±3, and 2 cases had scores below 60, with a mean of 51±11.31. The overall mean scores for IF and EF were 78.71±9.05 and 78.87±10.94, respectively, showing similar functional outcomes between both methods of fixation.

Table 2: Hospital for Special Surgery Knee-Rating Scale (HSSKRS) in both the methods of fixation

HSSKRS	IF		EF	
	No.	Mean	No.	Mean
Excellent (85-100)	5	91 + 2.74	9	92.33 + 2.5
Good (70-84)	13	77.31 + 3.95	24	77.88 + 4.42
Fair (60-69)	3	64.33 + 3.22	3	65 + 3
Poor (<60)	-	-	2	51 + 11.31
Mean	78.71 + 9.05		78.87 + 10.94	

Complications observed in the study were compared between the IF and EF groups, (Table 3). In the IF group, the complications included deep infection in 3 cases (5%), skin necrosis in 2 cases (3.3%), valgus collapse in 2 cases (3.3%), varus collapse in 1 case (1.7%), screw back-out in 5 cases (8.3%), and common peroneal nerve palsy in 2 cases (3.3%). In the EF group, deep infection occurred in 1 case (1.7%), valgus collapse in 2 cases (3.3%), varus collapse in 1 case (1.7%), and non-union in 1 case (1.7%). No skin necrosis, screw back-out, or common peroneal nerve palsy was observed in the EF group.

Table 3: Complications in both the fixation methods

Complications	IF	EF
	No. (%)	
Deep infection	3 (5)	1 (1.7)
Skin necrosis	2 (3.3)	-
Screw back out	5 (8.3)	-
Valgus collapse	2 (3.3)	2 (3.3)
Varus collapse	1 (1.7)	1 (1.7)
Non-union	-	1 (1.7)
Common peroneal nerve palsy	2 (3.3)	-

Discussion

The main objective when treating intra-articular fractures are for restoring a stable, properly aligned joints and return function and motion without pain. TPF, in particular, can be devastating, especially when there is significant damage to both bone and STs, or when the fracture is displaced, causing knee instability and misalignment [19]. No single management technique has proven consistently successful due to the varied nature of TPF.

Authors found that surgery performed within 2 weeks of trauma ideally on 1st day or post swelling has decreased is technically easier with ORIF. However, this depend on recovery of ST envelope, the orthopedist's experience, and the case's overall health. ST recovery is indicate by a reduction in swelling and blisters, as well as the return of skin wrinkles [20]. In this work, the HSSKRS functional at six months was similar to the score at 1 year, indicating that improvement in functional outcomes post six months is largely driven by physiotherapy rather than the surgical technique itself. Poor results were seen in cases who developed severe deep infections and required multiple surgeries afterward. Achieving stable fixation with EF is challenging without compromising knee function [21-24].

The study also found that dual incisions are generally better than a single incision for this type of surgery. In the current study, an anterior midline incision for IF was used, providing access to both condyles with a single incision.

The complexity of proximal tibial fractures, along with thin and vulnerable ST coverage, has led to an increased rate of severe complications, even when anatomical alignment and joint congruity are successfully restored with ORIF [22]. Authors reported a great deep infection rate despite using modern operations, widely small spaced incision plus minimal STs dissection and low-profiling implant in high-energy TPF [10]. As a result, alternative methods such as percutaneous reduction and stabilization using circular external fixators have been introduced.

In the present study, a case with a Type-3B open fracture (post wound-debridement) underwent IF, contrary to the usual guidelines. This case resulted in severe infection, requiring the plate to be removed and an external fixator applied. This outcome suggests that IF should be avoided in open-fractures-Type-3 [14].

The findings confirmed a high complications rate followed ORIF, despite the using of improved STs Handling technique. The deep infection rate in the ORIF arm was 7.89%, slightly lower than that mentioned by Barei *et al.* However, IF had higher infection rates compared to EF, often requiring implant removal and additional surgeries. EF, on the other hand, demonstrated lower deep infection rates and provided more flexibilities for STs Management, including plastic surgeries techniques like skin grafts or flaps [10].

Overall, limb alignments were successfully re-stored in all but 6 cases at the end of follow-up in 2 categories. Although bone grafts were initially planning, it wasn't performed during surgery, leading to delayed valgus collapsing. Bones-grafting must be considered when necessary, especially in cases with down bone fragment, for maintain joint congruities and preventing later collapsing. Although 1 case after all healed fractures in the EF group experienced nonunion. Reoperations in the ORIF group were typically more complex, often involving additional STs Procedure. Early joints congruities restoration, anatomical alignment, joints stabilities, and joint movements are critical to preventing early arthritis after intra-articular fractures [25].

Both IF with dual buttress plates and hybrid EF have notable limitations despite their effectiveness in managing high-energy TPF. IF, while providing anatomic dropping and hard fixation, is associated with risky STs Complications, particularly deep infections, because the invasive techniques. It also requires careful surgical skill, as achieving perfect reduction can be challenging, and there is a risk of delayed healing or nonunion. Additionally, despite early mobilization, there is always the possibility of knee stiffness if aggressive physiotherapy is not followed. On the other hand, hybrid EF offers advantages in preserving ST integrity and is especially beneficial in cases with compromised skin or Type 3 open fractures. However, it may not provide the same rigid stability as IF, and cases may experience more restricted joint movement during healing. EF also carries the risk of pin site infections, requires ongoing care, and can be cosmetically concerning due to the external frame. Both methods require strict case selection and close PO management, as improper choices or failure to follow rehabilitation protocols can lead to poor outcomes, such as joint stiffness or compromised fracture healing.

Conclusion

IF using dual buttress plates for high-energy TPF typically results in excellent to good functional outcomes. However, it is connected with a greater risk of ST outcomes, particularly deep infections. Dual plates help achieve anatomic decreasing and provide hard fixation of the articular surfaces, which facilitates early joint motilities. This early movement, combined with aggressive physiotherapy, helps prevent knee stiffness and promotes a more favorable functional recovery. Hybrid EF is a viable alternative, especially for cases with poor skin conditions, impended compartment syndromes, or Type-3 open fracture. This method provides strong stability while minimizing ST manipulation, which reduces the risk of complications. It also allows for easier secondary ST procedures. Both fixation methods can result in favorable outcomes for bicondylar TPF.

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