Original Article

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Functional Outcome of High Energy Schatzker Type V and VI Tibial Plateau Fractures Treated with Hybrid External Fixator: A Prospective Interventional Study

Orthopaedics Section

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ABSTRACT

Introduction: High-energy Schatzker type V and VI tibial plateau fractures are severely injured intra-articular fractures commonly accompanied by serious soft-tissue injury and instability. Conventional internal fixation may be problematic because of the serious risk of infection and soft-tissue complications. Hybrid external fixators provide a less invasive option, hoping to stabilise the fracture without compromising soft-tissue integrity and facilitating functional recovery.

Aim: To evaluate the functional results of hybrid external fixation of bicondylar tibial plateau fractures.

Materials and Methods: The present prospective interventional study was conducted at Government Doon Medical College, Dehradun, Uttarakhand, India over a period of 12 months from September 2021 to August 2023, focusing on high-energy Schatzker type V and VI tibial plateau fractures. A total of 41 patients were treated using a hybrid external fixator; however, three patients were lost to follow-up. Two-plane radiographs were taken in all the cases, and radiographs taken immediately after surgery were assessed to check the quality of fixation and reduction. All the patients were checked at six weeks, six months, and twelve months, and functional results were scored by the Modified Hospital for Special Surgery (MHSS) knee scoring system. Removal of the fixator was done at a mean of 2.5±0.5 months from the time of surgery. Data were analysed via statistical tests used Chi-square test or Analysis of Variance (ANOVA), with significance at $p<0.05$.

Results: Thirty-eight patients (31 men, 7 women) who had follow-up were included in the study. There were 13 Schatzker V fractures and 25 Schatzker VI fractures. All patients exhibited good coronal and sagittal plane alignment and preserved articular width on supine X-rays of the knee in Anteroposterior (AP) and lateral views. Good to excellent results were achieved in 36 (94.73%) patients based on the MHSS knee score. The average range of knee flexion was 115.79±21.29 degrees, and the average MHSS score was 80.34±10.30 at final follow-up. 2 (5.26%) patients got superficial infections after external fixation whereas 1 (2.63%) patients had nonunion, and another (2.63%) developed varus deformity. A total of 36 (94.74%) patients went back to their previous level of work and activity. No cases of deep infection were observed.

Conclusion: Hybrid external fixator in Bicondylar tibial plateau fractures gives a favourable functional outcome as it provides rigid fixation and allows immediate knee mobilisation.

Keywords: Bicondylar, Minimally invasive, Modified hospital for special surgery knee score

INTRODUCTION

Tibial plateau fracture, or intraarticular proximal tibia fracture, is a wide group of injuries to one of the weight bearing joints that is most often associated with functional disability [1]. According to the Schatzker Classification [2,3], it is then subdivided into six groups, S-I to S-VI. Various other methods of treatment have been described by various authors, each with its own merits and demerits. The most difficult fractures to treat for the orthopaedic surgeon for both osseous damage and restoration of the soft-tissue envelope are those affecting both condyles (S-V) and those which distract the metaphysis from the diaphysis of the tibia (S-VI) [4].

The level of stress transmitted across the proximal tibia, the age of the patient, and the bone quality all influence the injury pattern [5]. These bicondylar fractures encompass multiple displaced condylar fracture lines, significant articular depression, open or severe closed injuries, meniscal separation, Anterior Cruciate Ligament (ACL) injury, and metadiaphyseal fracture extension and comminution [6-8]. Schatzker VI fractures are commonly related to compartment syndrome in approximately 30% [9] of the cases.

They may also appear as open fractures in about 8.4 to 18% of the cases, and may lead to complications like wound dehiscence, joint stiffness, joint instability, nonunion, malunion, and post-traumatic arthrosis. Since the proximal tibia is subcutaneous, only a very thin soft-tissue envelope absorbs this energy. There are implications for the surgical treatment of the underlying bone injury because this soft-tissue envelope is not able to sustain prolonged and extensive dissection [10-12]. The goal of treatment for high energy tibial plateau fractures is to preserve alignment, congruity, and joint stability with minimal soft-tissue dissection, which aids in the knee joint's early mobilisation and reduces recognised problems [13]. Among the available treatment options are screws, unilateral periarticular locking dish, classic dual buttress plates, and hybrid dual plates, which combine a buttress plate and locking plate. hybrid external fixation. Major wound complications have historically been linked to Open Reduction and Internal Fixation (ORIF), particularly through compromised soft-tissues [14-16].

Schatzker type V and VI tibial plateau fractures are high-energy injuries often associated with devascularisation and severe soft-tissue damage, making management difficult. While ORIF is widely used, it carries a high risk of wound complications in such cases. Though hybrid external fixators have shown favorable results, limited prospective data exist on their long-term outcomes. Dual plating, though effective, is not ideal in cases with extensive soft-tissue injury due to healing issues [17]. This study aimed to evaluate the functional outcomes of using hybrid external fixation for managing these complex fractures. The primary aim of this prospective interventional study was to compare the functional results and complications of surgically treated bicondylar tibial plateau fractures

(Schatzker types V and VI) with a hybrid external fixator. This research will help bridge the knowledge gap by presenting evidence of the effectiveness of hybrid fixation in managing complex fractures, thus adding new insight into minimally invasive surgical solutions for such conditions. A convenience sample of 41 participants was enrolled in the study as per the eligibility criteria.

MATERIALS AND METHODS

This prospective interventional study was conducted at the Government Doon Medical College, Dehradun, from September 2021 to August 2023. Institutional Ethics Committee (IEC) approval was obtained prior to initiation of the study (GDMC/IEC/2021/104).

Inclusion and Exclusion criteria: Patients aged 18 years and above presenting with Schatzker type V and VI tibial plateau fractures were included in the study. Patients with Schatzker type I, II, III, and IV fractures, pathological fractures, vascular injuries, and those with insufficient follow-up were excluded.

Study Procedure

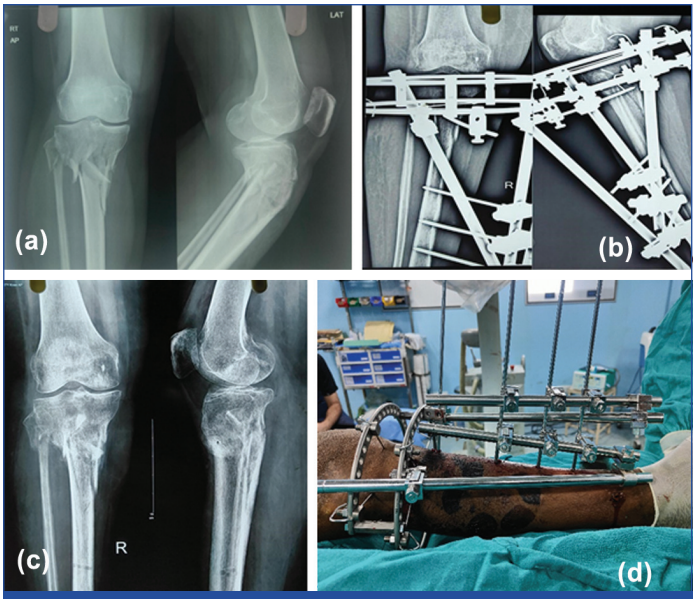
Forty one patients with Schatzker V and VI tibial plateau fractures were treated with a hybrid external fixator system. A follow-up of 12 months was completed for all patients. Information was gathered on patient age, gender, injury mechanism, side of injury, and concomitant injuries. Clinical findings such as neurovascular status, compartment syndrome, fracture blisters, and open wounds were documented. Radiological assessment consisted of AP and lateral knee X-rays and Computed Tomography (CT) scans with 3 Dimensional (3D) reconstructions for the purpose of evaluating fracture pattern, magnitude of articular depression, and metaphyseal-diaphyseal extension.

All the fractures were graded based on Schatzker's classification [2,3], and open fractures were graded additionally using the Gustilo Anderson classification [18]. Preoperative planning was done based on the fracture pattern. Patients were operated on after once medically stable, irrespective of swelling or skin condition. Antibiotic prophylaxis was given as follows: in the case of closed fractures, intravenous cefotaxime 1 gm with induction of anaesthesia, in open fractures, intravenous cefotaxime 1 gm, amikacin 500 mg, and metronidazole 100 mg were administered in the emergency department [19]. All cases were operated under fluoroscopic reduction. Fixation was carried out with a hybrid external fixator with or without supplementary percutaneous screws, according to intraoperative evaluation.

Patients were followed postoperatively at regular intervals for radiological union and functional results. Informed consent was obtained from all individual participants included in the study. The same operating team performed all cases, and a specific orthopaedic observer gathered data at every follow-up.

Operative procedure [Table/Fig-1]: Patients underwent surgery with regional anaesthesia while lying supine on a radiolucent operating table [20]. No tourniquet was applied to any of the patients. All fractures were initially managed using indirect reduction, with longitudinal traction and C-arm guidance. Depressed fractures were identified via C-arm imaging were elevated by creating a window in the anteromedial cortex using a bone tamp. Percutaneously inserted K-wires served as joysticks to make precise adjustments to the reduction of specific fragments or to rectify the tilt of articular fragments. After elevation, provisional fixation of the articular fragments to either the medial or lateral condyle was accomplished with K-wires. If necessary, the resulting metaphyseal gap was filled with autogenous cancellous bone graft harvested from the ipsilateral iliac crest.

In some cases, the stabilisation of the articular fragments was achieved by inserting large fragment cannulated screws (6.5 mm) with or without washer, percutaneously parallel to the joint within



[Table/Fig-1]: a) Preoperative X-ray - AP and Lat views; b) Postoperative X-Ray - AP and Lat views; c) Final follow-up X-ray - AP and Lat views; d) Hybrid fixator.

the subchondral bone across the main fracture lines in a lag configuration. Following the reduction of the articular surface, a hybrid external fixator frame was applied to secure the metaphysis to the diaphysis of the tibia. The circular frame was constructed using either two rings or a single ring, depending on the extent of the fracture fragments. The rings were tailored to the limb to allow for 3-4 cm of circumferential clearance. The lag often tends to sag posteriorly against the frame; thus, sterile towels or sponges were used to maintain this clearance at the back throughout the procedure.

The proximal wires were positioned such as to prevent intra-articular penetration. Either 1.8 mm Olive wires or Plain wires, depending on the fracture fragment, need to be compressed. If the lateral condyle fragment is displaced, then the olive wire is inserted from lateral to medial to compress the fragment while tensioning from the other side. The first wire was horizontally inserted from lateral to medial, anterior and proximal to the center point of the fibular head. The second wire was positioned from posteromedial to anterolateral, maintaining an angle of 30 to 60 degrees between the wires. The ring was then assembled with the wires, which were tensioned using a dynamometric tensioner. The rings were connected to one another, and the assembly was reinforced with Schanz pins in the rings for added stability. The ring structure was integrated with the uniplanar construct using 4.5 mm Schanz pins placed 3-4 cm apart on the anteromedial surface of the tibia, with drill holes created using a 3.2/3.5 mm drill bit in the same sagittal plane. This ring structure was then connected with a uniplanar construct using connecting rods in a Triangular fashion.

In cases of potential compartment syndrome, a fasciotomy was performed involving two incisions: one on the posteromedial aspect and another on the anterolateral aspect of the leg wound, which was left open and covered with a moist sterile dressing. A split skin graft was carried out two days afterward.

Postoperative X-rays were analysed to evaluate the effectiveness of articular reduction, metaphyseo-diaphyseal reduction, and alignment. Antibiotic treatment was administered postoperatively for a duration of five to seven days. Patients were encouraged to perform active digital movements and to elevate the limb to minimise swelling in the toes. No knee immobilisation was employed. The patient was discharged on the second or third postoperative day. Non-weight bearing mobilisation utilising a walking frame, along with quadriceps exercises, was commenced on the first day after the operation. Gait training with partial weight bearing started at 12 weeks after the surgery, gradually progressing to full weight

bearing between 16 and 20 weeks. The removal of the hybrid external fixator occurred after an average of 2.5±0.5 months, followed by the application of a Patellar Tendon-Bearing (PTB) cast to promote progressive weight bearing mobilisation.

Regular review of patients was conducted at six weeks, six months, and 12 months until radiological union and optimal functional recovery were achieved. During each follow-up visit, data regarding fracture healing and knee joint range of motion were systematically recorded. Radiological assessment included routine AP and lateral views to evaluate cortical continuity, trabecular bridging, and alignment. Functional outcomes were evaluated using the MHSS [21] Knee Scoring System, a standardised tool that assesses pain, stability, range of motion, and muscle strength, with deductions for deformities such as extension lag, fixed varus, and valgus. The scoring system has a total of 100 points, and the grading was as follows: excellent (85-100), good (70-84), fair (60-69), and poor (<60) [22]. The MHSS knee score is a well-validated and widely used tool known for its good interobserver reliability and sensitivity to postoperative changes. At each follow-up, patients completed the scoring proforma through a structured interview and clinical examination, and their responses were systematically documented.

STATISTICAL ANALYSIS

Data were gathered in Microsoft Excel and processed using IBM Statistical Package for Social Sciences (SPSS) Statistics version version 25.0. Descriptive statistics like mean, Standard Deviation (SD), frequency, and percentage were utilised for summarising continuous and categorical variables, respectively. Data analysis was performed using SPSS version 25.0 (IBM), where categorical data were presented as frequencies and percentages, and continuous data were expressed as mean±SD or median (25^{th}-75^{th} percentile). The Chi-square test and the ANOVA test were utilised to analyse categorical data. A p-value of <0.05 was considered statistically significant.

RESULTS

Forty-one patients with Schatzker type V and VI tibial plateau fractures were treated in the Government Doon Medical College, Dehradun, Uttarakhand, India from September 2021 to August 2023. Three patients were lost to follow-up. There were 38 remaining patients- 13 type V fractures and 25 type VI fractures- entered into this prospective interventional study. Thirty-one patients were male, and seven were female. The majority of injuries (n=36) resulted from vehicular accidents, while two were due to falls from height. Eighteen patients had left-sided fractures and 20 patients had right-sided fractures. Patient age ranged from 21 to 64 years, with a mean of 42.5±11.4 years. Hospital stays ranged from four to eight days. All patients were followed for 12 months postoperatively. Five patients had open fractures [Table/Fig-2].

Schatzker type	Closed fractures	Open fractures (Gustilo-Anderson)	Total	Knee flexion Mean±SD
V	12 (31.58%)	1 (II) (2.63%)	13 (34.21%)	119.67±12.45
VI	21(55.26%)	4 (I, II, II, IIIB) (10.53%)	25 (65.79%)	113.75±14.20
Total	33	5	38	-
p-value				0.63

[Table/Fig-2]: Fracture distribution according to type.
(Chi-square test for Knee Flexion association between fracture type)

Injuries associated with these were cruciate ligament injuries in 2 (18.18%) patients (one anterior cruciate ligament and one posterior cruciate ligament), and collateral ligament sprains in 3 (27.27%) patients. Only 1 (9.09%) patient had impending compartment syndrome. Prior to surgery, none of the patients had nerve palsy. Five patients had additional bone injuries, which were treated conservatively: three had Ipsilateral Colles' fractures, one had a clavicle fracture, and one had a contralateral Jones fracture [Table/Fig-3].

Associated injuries	No. of cases
Impending compartment syndrome	1 (9.09%)
Cruciate ligament injury	2 (18.18%)
Collateral ligament strain	3 (27.27%)
Other fractures	5 (45.45%)

[Table/Fig-3]: Associated injuries.

Surgery was conducted at an average interval of 41±14.2 hours (range of 8-74 hours), depending on the severity of injury and patient status. An emergency operation for imminent compartment syndrome included hybrid external fixation, a two-incision fasciotomy, and a split-thickness skin graft performed 48 hours later. Primary bone grafting was conducted through an anteromedial window in two type VI fractures. Mean operative time was 1.35±0.15 hours. Fluoroscopy was employed in every case. Postoperative radiographs in AP and lateral projections immediately post-surgery established satisfactory articular reduction and meta-diaphyseal alignment.

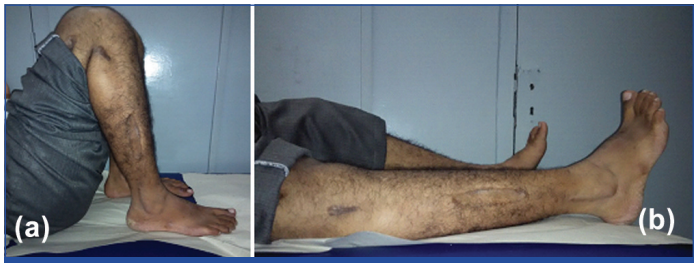
Patients were evaluated with the Modified HSS (MHSS) Knee Scoring System at 12 months. 13 (34.21%) patients were rated between 85 and 100 (excellent), 23 (60.53%) patients rated between 70 and 84 (good), and 2 (5.26%) patients rated below 60 (poor), as illustrated in [Table/Fig-4]. Functional results differed depending on fracture type. At final follow-up, mean knee flexion was 115.79±21.29 degrees in general, with type V fractures demonstrating a mean of 119.67±12.45 and type VI a mean of 113.75±14.20, showing (p-value 0.63) no significant change in range of knee motion, 7 (53.85%) patients had excellent results in Schatzker V fracture pattern, and 6 (24%) patients had excellent results in Schatzker VI fracture pattern [Table/Fig-5]. An extension lag of 10 degrees was developed by three patients [Table/Fig-6].

Modified HSS score	Number of patients
<60 (Poor)	2 (5.26%)
60-69 (Fair)	0 (0.00%)
70-84 (Good)	23 (60.53%)
85-100 (Excellent)	13 (34.21%)
Total	38 (100.00%)
p-value	<0.001

[Table/Fig-4]: Modified HSS (MHSS) SCORE at final follow-up.
(Chi-square goodness-of-fit test for HSS score distribution)

Modified HSS score	Schatzker V n (%)	Schatzker VI n (%)
<60	0	2 (8%)
60-69	0	0
70-84	6 (46.15%)	17 (68%)
85-100	7 (53.85%)	6 (24%)
Total	13	25

[Table/Fig-5]: Modified HSS (MHSS) score at final follow-up according to the fracture pattern.



[Table/Fig-6]: Knee range of motion in: a) Flexion at final follow-up; b) Extension at final follow-up.

[Table/Fig-7] shows the progression of MHSS scores over three time points: six weeks, six months, and 12 months. At six weeks, the mean MHSS score was 35.68±9.52. By six months, the

mean MHSS score improves to 66.76, with a slightly higher SD of 11.10, suggesting a greater variation in scores but still a notable improvement in overall function. By 12 months, the mean MHSS score reached 80.34, with a slightly lower SD of 10.30, showing further improvement in scores and a more consistent result across the group. Overall, these results suggest that patients' health and function significantly improve over time, with the greatest improvement occurring between six weeks and six months.

Time period	Mean	SD
6 weeks	35.68	9.52
6 months	66.76	11.10
12 months	80.34	10.30
p-value	0.011	

[Table/Fig-7]: Mean Modified HSS (MHSS) Score progression over time.
(Repeated Measures ANOVA to assess changes over time)

Complications were noted in a few patients [Table/Fig-8]. A 2 (5.3%) patients had superficial infection, 1 (2.6%) had varus collapse with malalignment due to a fall two weeks after surgery (who was lost to follow-up and presented at six weeks), and one had nonunion. Two (5.3%) patients also developed postoperative common peroneal nerve palsy, which resolved completely in both patients within six weeks. Three patients needed further procedures. One had a split-thickness skin graft for the wound of fasciotomy had a good functional outcome. A second patient, with varus malalignment and collapse secondary to postoperative trauma, was treated with corrective osteotomy and plating along with bone grafting at three months. The third patient with non-union underwent bone grafting and plate fixation at five months. Both these patients had a poor functional outcome at the time of final follow-up.

Complications	No. of cases
Superficial infection	2 (5.3%)
Varus collapse	1 (2.6%)
Common peroneal nerve palsy, neuropraxia	2 (5.3%)
Non-union	1 (2.6%)
p-value	0.131

[Table/Fig-8]: Complications postsurgery.
(Chi-square test for complications postsurgery)

DISCUSSION

This study aimed to assess the clinical and functional efficacy of hybrid external fixation as a definitive treatment modality for Schatzker type V and VI tibial plateau fractures, including both closed and open injuries. The findings suggest that hybrid external fixation, when supplemented with minimal internal fixation as needed, yields favorable outcomes in terms of fracture stabilisation and joint function. The MHSS scores recorded over a one-year follow-up period had good to excellent outcomes in 36 (94.73%) patients, underscoring the efficacy of this approach in enhancing joint stability and functional recovery. Physiotherapy played a significant role in improving functional scores after six months postoperatively. One patient failed to restore overall limb alignment by the time of the final follow-up. This was attributed to the failure to perform bone grafting during surgery, which had been planned preoperatively. The delayed varus collapse observed in this case underscores the importance of bone grafting for maintaining articular congruity and preventing late collapse in cases involving depressed bone fragments.

A stable, aligned joint with painless motion and functional restoration is the primary goal of treatment for any intraarticular fracture. Tibial plateau fractures can result in significant injuries, particularly when there is substantial involvement of bone and soft-tissues, and the injury is displaced, causing knee instability and joint incongruity. The literature has extensively examined the role of the soft-tissue envelope in tibial plateau fracture healing, with studies showing that poor outcomes are associated with extensive soft-tissue damage [16,23-26]. Given the diversity of tibial plateau injuries, no single technique has consistently demonstrated ideal results.

The present findings reinforce the notion that while both internal and external fixation methods are efficacious, hybrid external fixation may offer distinct advantages by minimising soft-tissue disruption and non-significant complication rates. Barei DP et al., reported a high incidence of deep infections in high-energy bicondylar tibial plateau fractures managed with dual plating, even when employing contemporary techniques such as delayed definitive surgery (mean nine days post-injury), limited soft-tissue dissection, and low-profile implants [12]. Similarly, Young MJ and Barrack RL reported a deep infection rate of 88% with dual plating in complex bicondylar tibial plateau fractures [16]. Bertrand ML et al., (2017) compared ORIF with hybrid external fixation for severe tibial plateau fractures and highlighted comparable or superior outcomes with hybrid fixation in terms of soft-tissue preservation and infection control [24].

Over the past two decades, the adoption of biologic osteosynthesis and minimally invasive surgical approaches has increased in the management of comminuted tibial plateau fractures, paralleling advances in external fixation technologies. The development of circular and hybrid fixator systems has enhanced the ability to provide stable fixation in complex cases through features such as axial and lateral compression and improved wire configurations, including the use of olive wires [25]. Chin TYP et al., observed that 38.9% of patients achieved good to excellent outcomes, while 61.1% had fair to poor outcomes following hybrid external fixation for bicondylar tibial plateau fractures [26]. Conversely, Aggarwal AK et al., reported good to excellent outcomes in 76.2% of patients treated with hybrid fixation [27]. Catagni MA et al., documented that among patients treated with circular external fixators for Schatzker V and VI fractures, 50.85% had excellent and 45.76% had good outcomes [28]. In another study, Juneja J et al., (2022) evaluated 20 patients with high-energy Schatzker type V and VI fractures managed with hybrid fixation and concluded that the technique ensured sufficient stabilisation while promoting soft-tissue healing [29]. Supporting this, the Canadian Orthopaedic Trauma Association noted superior HSS scores at six months and fewer early postoperative complications in the external fixation group compared to internal fixation, with no significant difference observed in osseous reduction or range of motion between groups [30]. The present study also shows excellent outcomes in 34.21% and good outcomes in 60.53%, with a significant improvement at six months and 12 months postoperatively, which goes in favour of the previous studies done.

Regarding complications, the rate of pin-site infection in this study was 5.3%, which is notably lower than the 10% incidence reported in a meta-analysis encompassing 16 trials on tibial plateau fractures [31]. This finding reflects improved techniques in pin care and fixator management. The early restoration of joint congruity, maintenance of anatomic alignment, joint stability, and initiation of early mobilisation have been recognised as critical factors in minimising the risk of early degenerative joint changes following intra-articular injuries [32]. Gross JB et al., (2017) retrospectively analysed 40 cases and concluded that hybrid external fixators were associated with lower infection rates and favourable functional results in the management of complex tibial plateau fractures [33]. Similarly, Ariffin HM et al., demonstrated that the modified hybrid external fixator is a reliable and effective treatment modality for complex Schatzker V and VI injuries, offering benefits such as reduced soft-tissue complications and satisfactory bony union. The predominant complication observed in their study was pin tract sepsis [34].

Limitation(s)

Not all the procedures in the present study were done by a single surgeon, there were several surgeons involved. The follow-up was at most 12 months, which precludes determination of long-term

measures such as secondary knee arthritis. In addition, the absence of a comparison group (e.g., patients undergoing internal fixation) restricts the potential to establish if hybrid external fixation is better than other treatments.

CONCLUSION(S)

External fixation with a Hybrid Fixator for high-energy tibial plateau fractures offers an excellent to good functional outcome. The hybrid external fixator obtains anatomic reduction and rigid fixation of the articular surface via percutaneous methods, enabling immediate joint mobilisation. This allows early and aggressive physiotherapy, precludes knee stiffness, and leads to a good functional outcome with fewer complications than open fixation techniques. More multicenter trials with bigger sample sizes and longer follow-up times are suggested in order to confirm these results. Comparison trials of hybrid external fixation versus other minimally invasive or internal fixations would yield further insight into the best treatments for tibial plateau fractures. Cost-effectiveness, as well as patient-reported outcomes, would further strengthen the clinical decision-making process.

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