Management of open complex tibial plateau fractures by Ilizarov fixator: average follow-up of 8.5 years

Abdel-Salam A. Ahmed

Department of Orthopaedic Surgery, Benha Faculty of Medicine, Farid Nada Street, Kalyubia, Benha, Egypt

Correspo ndence to Abdel-Salam A. Ahmed, MD, Department of Orthopaedic Surgery, Benha Faculty of Medicine, Farid Nada Street, Kalyubia, Benha 13518, Egypt.
Tel: +20 114 437 0370, +20 133 263 343;
e-mails: salam_ilizarov@yahoo.com, abdelsalam.youssef@fmed.bu.edu.eg

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Introduction
Open tibial plateau fractures are associated with significant soft tissue injuries which increase the risks of complications and their management is highly challenging. Ilizarov external circular fixation is an ideal method of treatment when extensive soft tissue dissection and internal fixation are contraindicated. This retrospective study aimed to evaluate the mid-term results of managing open complex tibial plateau fractures with Ilizarov fixator.
Patients and methods
The study included 27 patients with open tibial plateau fractures (Schatzker types V and VI) with a mean age of 40.56 years. They included 17 men and 10 women. Sixteen fractures were of open type III-A and 11 were type III-B according to the Gustilo classification. Seven cases had associated injuries. Five patients had previous temporary spanning external fixation. Three patients were diabetics. Above knee frame extension was done in 14 cases. Assisted wound closure by the frame was done in three cases.
Results
All fractures were fully united with a mean fixator period of 18.37 weeks. The average follow-up duration was 8.52 years. No patient developed a deep infection. According to the ASAMI score, the results were evaluated as excellent in nine patients, good in 14 patients, and fair in four patients. The overall result was judged as satisfactory by all patients.
Conclusion
The treatment of complex tibial plateau fractures with the Ilizarov fixator is a safe, versatile, and an effective treatment option, and produces good functional results. It also allows early full weight-bearing and good rehabilitation.

Keywords:
complex tibial plateau fractures, Ilizarov external fixator, open fractures, soft-tissue traction

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Introduction

Open complex fractures of the tibial plateau are one of the most challenging problems in orthopedic surgery representing a serious problem for both the patient and the orthopedic surgeon [1–3]. Closed methods of treatment with traction or cast bracing are usually unsuccessful in maintaining articular reduction and axial alignment. Traditional methods of open reduction and internal fixation (ORIF) with plates and screws require extensive exposure and soft tissue stripping, which may compromise soft tissue further and devascularize the bone fragments [2–4].

ORIF of complex tibial plateau fractures have high rate of complications, mainly infections, post-traumatic deformities, inability to obtain a reduction, and wound breakdown [1,5]. To decrease the incidence of these complications, many authors have recommended minimally invasive techniques such as isolated lateral plating, hybrid external fixation, and tensioned-wire fixation [6–8]. The advent of locking plates applied through limited approaches has significantly decreased the amount of external fixation used for definitive treatment of shaft-dissociated and bicondylar patterns [7,9]. However, in open fractures, external fixation is the workhorse for skeletal stabilization as it provides a swift versatile method of providing stability without the need for additional exposure or periosteal striping even in demanding situations [1,5,10]. The external circular fixator, originally introduced by Ilizarov, is being widely used today in the management of open fractures [1,4,9,10].

The purpose of this study was to evaluate the long-term functional, clinical, and radiological outcomes of Ilizarov fixation in patients with high-energy open fractures of the tibial plateau.

Patients and methods

This retrospective study included 27 patients with open tibial plateau fractures operated upon from January 2002 till June 2010 at Benha University Hospital, Egypt. The inclusion criteria for this study included open fractures of the tibial plateau with Schatzker classification V and VI [11] treated by Ilizarov external fixator. Exclusion criteria were pathological fractures of the tibia and patients lost to follow-up. Ten patients were women and 17 were men with a mean age of 40.56 years (SD: 9.69; range 23–57 years). Three patients were diabetics and eight were smokers. All fractures were due to high-energy trauma. The mechanisms of fracture were as follows: 21 cases were caused by road traffic accidents, four cases were secondary to falls from a height, and two cases were caused by work-related injury.

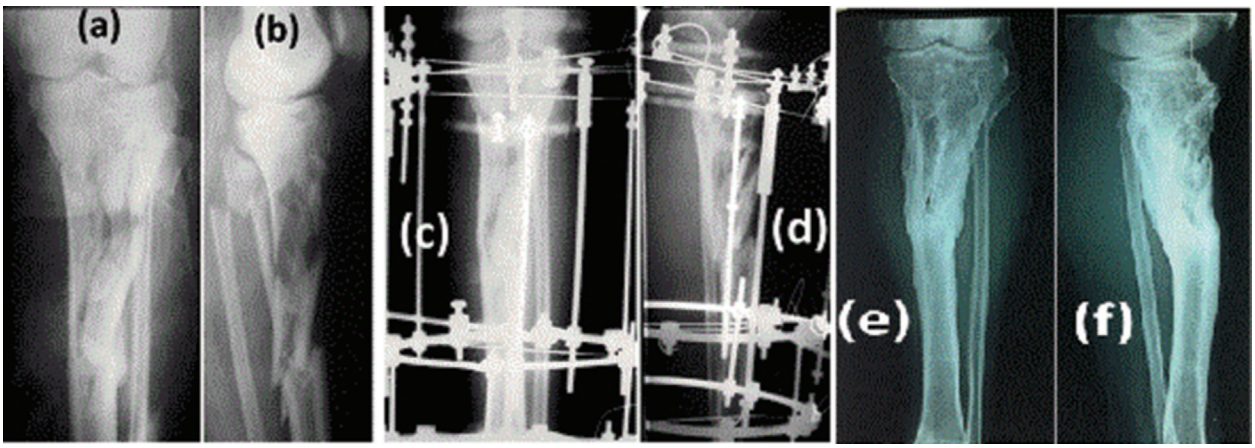
Eight cases were Schatzker type V and 19 were Schatzker type VI. According to Gustilo and Anderson classification [12], 16 fractures were open type III-A and 11 were type III-B. All cases were unilateral with 18 left and nine right fractures. Seven cases had associated injuries including ipsilateral femoral fractures (four cases), rib fractures (one case), lateral popliteal nerve injury (one case), and humeral fracture (one case). Five patients had previous temporary spanning external fixation done in another referring hospital. At the time of hospital admission, standard trauma evaluation and thorough clinical and radiographic evaluation was carried out for full assessment of injuries. A computerized axial tomography scan was obtained for better fracture identification and preoperative planning. Arteriography was done in three cases of Schatzker type VI fractures to exclude vascular injury. The time period between the trauma and the surgery ranged from 8 h to 13 days with a mean of 3.85 days (SD: 3.31 days). Post-traumatic soft tissue swelling did not influence the timing of surgery.

On admission, all open fractures were treated emergently with irrigation, debridement, intravenous antibiotics, and tetanus prophylaxis. Every attempt was made to cover the exposed part of the bone with soft tissue. Preoperatively, skeletal trans-calcaneal traction was performed for four patients in whom surgery was delayed. A combination of aminoglycoside and cephalosporin was given for 3 days and then the cephalosporin alone for additional 7 days. Anticoagulant therapy with low-molecular heparin was administered from the day of hospital admission for up to 14 days after leaving the hospital.

Operative technique

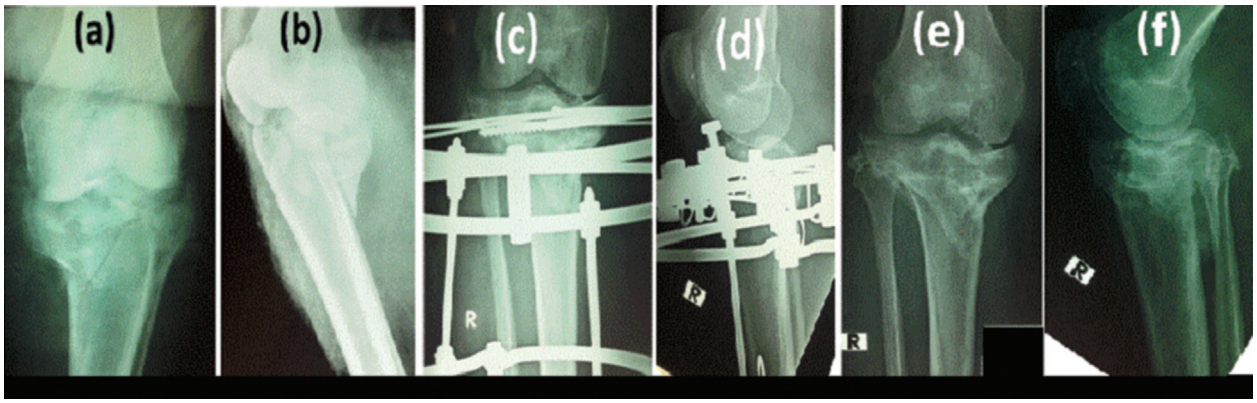
The operation was performed under spinal or general anesthesia. The patient was positioned on the traction table. Arthrocentesis was done to decrease intraarticular pressure. Fluoroscopy was used during the reduction, insertion of olive wires, and during frame adjustment. Closed axial reduction by ligamentotaxis was achieved by traction and assisted by elevators through the traumatic wound and a large reduction forceps placed percutaneously to achieve adequate condylar compression. Once satisfactory reduction of the articular surface had been achieved, opposing olive wires were placed through the fragments to maintain interfragmentary compression. Wires were introduced at least 15 mm away from and parallel to the joint surface for stabilization of the condylar and metaphyseal fragments (Fig. 1). Occasionally, that was strengthened by one or two

Figure 1



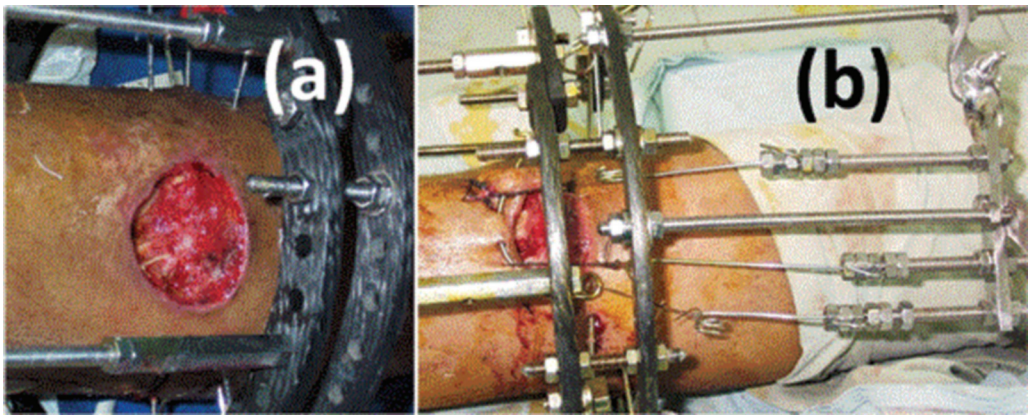
Comminuted fracture of tibial plateau and proximal tibia: (a, b) preoperative radiographs, (c, d) postoperative radiographs with frame fixation by wires, and (e, f) radiographs at 10 years follow-up.

Figure 2



Another case of comminuted tibial plateau fracture: (a, b) preoperative radiographs, (c, d) postoperative radiographs, (e, f) radiographs at 3 years of follow-up.

Figure 3



Skin traction device: (a) open gapping circular wound, (b) a K-wire was applied to the skin 1 cm from the edge of the wound and was connected to hooked wires that were attached to the frame by slotted rods.

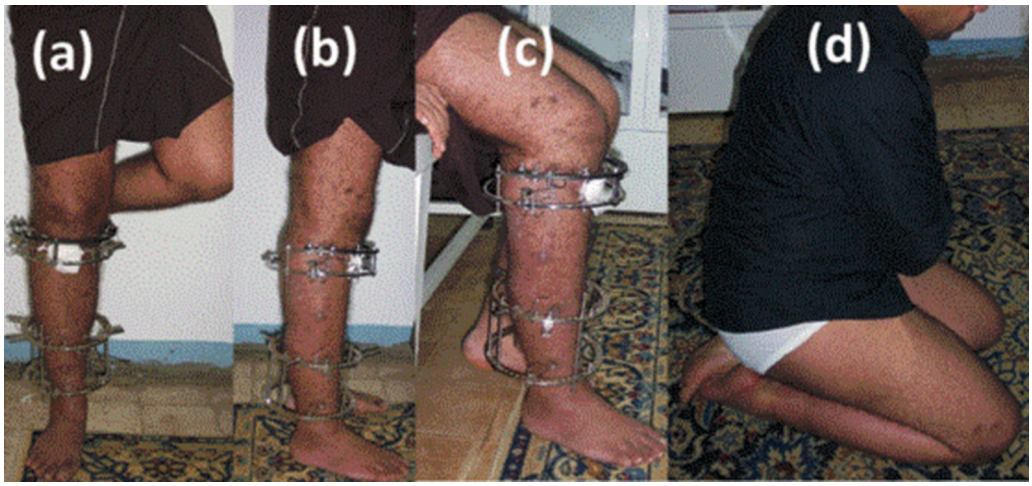
half-pins (Fig. 2). These wires were tensioned over an appropriate-sized ring. With more distal extension of the fracture, a ring block formed by 5/8 ring and a ring was used instead of using drop wires. Bone grafting was not performed in this study.

A ring block formed by two appropriate-sized rings was fixed to the tibia. The proximal ring was placed 2–3 cm distal to the fracture and the distal ring was placed 3 cm proximal and parallel to the ankle joint. Then, that ring block was connected to the proximal ring with metaphyseo-diaphyseal fracture reduction. The comminuted metaphyseal region was thereby bridged and remained *in situ*. With marked fracture comminution, the frame was extended into the distal femur. To assist coverage in major soft-tissue defects, a soft-tissue traction device was applied in three cases. A K-wire was applied to the skin 1 cm from the edge of the wound and connected to hooked wires that were attached to the frame by slotted rods (Fig. 3).

Postoperative care

Isometric quadriceps exercises were started from the second postoperative day. Early knee motion was encouraged in the cases without femoral extension of fixator. Initially, touch weight-bearing was allowed. Then at 3 weeks, it was advanced to partial weight-bearing as tolerated reaching full weight-bearing with complete union. Assisted wound closure by skin traction was done at 1 mm daily. Patients were followed up clinically weekly till sound wound healing and clinically and radiographically monthly until fracture union. Thereafter, the follow-up was every 6 months for the first year after injury, and then every year. The patients were monitored for pin care, maintenance of position and alignment, range of motion (ROM), progression of weight-bearing, and progression of healing. The femoral frame was removed at an average of 4 weeks. In the resting position, the knee was gently forced into full extension by placing a pillow under the last ring.

Figure 4



Clinical photographs: (a, b) testing clinical union. The patient is standing without pain after the connecting rods had been removed. (c) Range of flexion before frame removal. (d) One year after removal, the patient had excellent range of motion.

The fractures were regarded as being healed when the radiographs showed a bridging callus and the fracture was stable when stressed manually and the patients were able to walk without pain after the connecting rods had been removed (Fig. 4). The fixator was removed under general anesthesia to permit concomitant manipulation. All patients received physiotherapy during external fixation and after removal of the frame. Evaluation of patients was done using the scoring criteria of the Association for the Study and Application of the Method of Ilizarov (ASAMI), Italy [1]. The outcome was classified as poor (score<59), fair (score=59–69), good (score=70–79), and excellent (score=80–90) (Table 1).

Statistical analysis

Qualitative variables were expressed as an absolute value (*n*), while the quantitative variables were expressed as means, SD, and ranges. Pearson's correlation coefficient was used to analyze the relationships between the final ASAMI score and factors such as age, the time period from injury to surgery, and subjective patient satisfaction. Statistical analysis was done to compare the ROM immediately after frame removal and at the last follow-up using Student's *t*-test. Level of significance was set at *P* values of less than 0.05. Descriptive and statistical analyses were performed with IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, New York, USA).

Results

The average duration of hospitalization was 17.44 days. (SD: 6.89; range: 8–32 days.) Patients were followed up for a mean of 8.52 years (SD: 2.51; range: 3.5–13 years). Above knee femoral frame extension was done in 14 cases due to marked fracture comminution and skin traction for wound closure was done for three cases. All fractures were fully united with a mean external fixator period of 18.37 (SD: 2.186; range: 16–25) weeks. All wounds healed within 2 weeks after surgery except cases with skin traction healed within 4 weeks. All cases had full knee extension. The range of knee flexion just after frame removal averaged 81.48° (SD: 10.81°; range: 55°–95°). At the last follow-up visit, it was 122.78° (SD: 14.37°; range 90°–145°) with significant improvement (*P*=0.000). Four patients had a range of flexion 100° or less. All patients regained the capacity of full weight-bearing and functional use of the limb. Two patients had tibial shortening of 1.5 cm. Three patients had an articular depression of 5 mm and five patients had a depression of 2–3 mm. One patient had a valgus angle of 8°. Most final radiographs showed some degenerative changes reflecting the age of the patients. Nine patients had no pain, while the remaining 18 had mild or occasional pain. The case of lateral popliteal nerve palsy caused by the trauma, resolved spontaneously 8 months after frame removal.

Superficial pin track infection was recorded in 15 patients and controlled by local pin site care and oral antibiotics. There was no loosening of frame due to pin tract infection. Deep venous thrombosis occurred in one patient. There was no deep infection, ring sequestrum, osteomyelitis, or septic arthritis. None of the patients developed vascular injury or common peroneal nerve injury related to inadvertent Kirschner wire penetration. No patient had gross knee instability or refracture after frame removal.

Table 1 ASAMI scoring criteria of results for complex fractures of the tibial plateau

Variables	Score
Bone results	
Union without infection	30
Nonunion or infection	0
Radiology results	
Good joint line	10
Malalignment <2 mm	8
Malalignment 2–4 mm	6
Malalignment >4 mm	0
Knee range of motion	
>130°	10
110°–130°	8
80°–109°	6
<80°	4
Leg length discrepancy	
No leg discrepancy	10
<1 cm	8
1–2 cm	6
2–4 cm	3
>4 cm	1
Pain	
Absent	10
After sport activity	9
After long walking	8
Weather related only	7
After short walking	4
Mild activity related	2
Night pain at rest	1
Sporting activity	
Full return to previous sport activity	10
Decreased sport performance	8
Poor sport performance	4
No sport ability	0
Subjective patient satisfaction	
Full satisfaction	10
Mild dissatisfaction	8
Medium dissatisfaction	4
Dissatisfaction	0

[a]Excellent: score=80–90; good: score=70–79; fair: score=59–69; poor: score <59.

According to the scoring criteria of ASAMI, Italy, the results were excellent in nine (33.3%) cases, good in 14 (51.9%) cases, and fair in four (14.8%) patients. None of the patients had poor score. Subjective patient satisfaction was significantly related to the ASAMI score (Pearson's correlation=0.716, *P* 0.000). There was no correlation between age and final ASAMI score (Pearson's correlation=0.007, *P*=0.973) or between the time period from injury to surgery and the ASAMI score (Pearson's correlation=0.312, *P*=0.114).

Discussion

The treatment of tibial plateau fracture patterns has been extensively reported in the literature. Despite this, the optimal technique for a given fracture is uncertain [4,9]. The comminuted fractures are one the most difficult to treat with ORIF. Skin conditions are bad and more complicated when the fracture is open as in many cases. Open reduction and stabilization are very difficult or impossible [1,13,14]. A randomized study of bicondylar fractures by the Canadian Orthopaedic Trauma Association found that patients treated with circular external fixator had similar or better outcomes with less complications than those treated with dual plating [15]. The Ilizarov fixator is respectful of the biology of the bone and soft tissue, able to obtain ligamentotaxis as well as compression across the fracture site, versatile, and is effective in providing stability allowing early postoperative joint mobilization with partial weight bearing. Stabilization of short periarticular fragments is possible with thin wires. In addition, maintenance of the mechanical axis can be continually monitored and corrected by adjustment of the frame [1,4,13,16]. Some studies support a two-staged protocol for high-energy proximal tibial fractures [17]. The Ilizarov method gives the advantage to operate on all patients without delay [1,2,18]. Problems with the Ilizarov frame include complexity of application, a bulky frame requiring patient compliance, and the risk of specific complications such as pin-tract infection, pins loosening, and neurovascular injury [1,2].

In this study, 27 open tibial plateau fractures (Schatzker types V and VI) were treated by Ilizarov fixator. Successful union was achieved in all patients with a mean external fixator period of 18.37 weeks which is comparable with the mean fixator period in other studies [1,2,4,6]. Above knee femoral frame extension was done in 14 cases with marked fracture comminution to improve the stability and reduce the forces on the articular surface and lessen the risks of loss of reduction. A soft-tissue traction device was applied in three cases to aid in wound coverage based on the concept of distraction histogenesis [19]. There is no report on using this technique by Ilizarov fixator for open tibial plateau fractures. Hosny and Fadel [20] reported that in four cases of 34 open tibial diaphyseal fractures.

In this study, the bone grafting was not performed. Catagni *et al.* [1] and Ariffin *et al.* [14] did not use bone grafting. Lalić *et al.* [2] reported bone grafting in 13 of 50 cases and Ali [4] used bone graft in five of 25 fractures. Minimal internal fixation using percutaneously inserted lag screws was used with circular and hybrid fixators. El Barbary *et al.* [21] reported that in 18 of 30 cases, whereas Ali [4], Ali *et al.* [6], and Weiner *et al.* [22] used screw fixation in

all of their fractures. On the contrary, Catagni *et al.* [1] and Dendrinos *et al.* [16] used only external fixation wires without screws. In the current series, internal screw fixation was not used. That was based on the observation that small tensioned wires allow capture of small bone fragments and olive wires can compress the condylar fractures as would lag screws [16]. Moreover, the circumferentially supported and tensioned wires in the subchondral bone function as a scaffold supporting the tibial plateau [6,13].

All patients in this series achieved full extension. This was mainly because of early rehabilitation and proper positioning because when the patient is supine the ring fixator surrounding the leg tends to flex the knee. Extension lag was reported in three of 33 cases with Ariffin *et al.* [14], in seven of 24 cases with Dendrinos *et al.* [16], and in five of 43 cases with Reddy *et al.* [3]. In the current study, the range of knee flexion at the final follow-up was 122.78° with significant improvement from ROM just after fixator removal. Early motion and programmed physiotherapy after surgical treatment is a standard care. This ROM is comparable to other studies [13,14,18], and better than ROM reported by Ali [4] (112°; range: 50°–125°), and El Barbary *et al.* [21] (112.5° with three cases less than 60°). Catagni *et al.* [1] found that the patients' knee ROM was always increasing at consecutive clinical evaluations. Immobilization of the knee for up to 6 weeks does not seem to adversely affect the ultimate knee ROM [5,9]. However, Ali *et al.* [6] reported all the poor results in the group who had cross-knee fixation.

Mild or occasional pain was reported in 18 cases of the present series. Kumar *et al.* [13] reported pain on walking in 20% of cases of type VI tibial plateau fractures and 80% of cases of types IV and V. Lalić *et al.* [2] reported moderate pain in 45 of 50 patients. In the current study, three patients had an articular depression of 5 mm and five patients had a depression of 2–3 mm. One patient had a valgus angle of 8°. Ali [4] reported articular depression in seven cases (three >4 mm, and four <4 mm) and three varus deformities in 25 cases. Ramos *et al.* [18] reported depression of at least 7 mm in three cases and three valgus and two varus deformities in 30 cases.

This study is consistent with others within the literature, showing no evidence of septic arthritis or deep infection [1,2,6,16]. To avoid the occurrence of septic arthritis, the most proximal pins in the tibia must remain at least 14 mm distal to the joint line to prevent violation of the capsule of the knee [9,23].

Table 2 The present study compared with the literature

Number of patients	This study 27	Catagni *et al.* [1] 59	Lalić *et al.* [2] 50	Reddy *et al.* [3] 43	Ali [4] 25	Ali *et al.* [6] 21	Ramos *et al.* [19] 30
Open/closed fracture	Open	5 Open	28 Open	Closed	Open	5 Open	Closed
Schatzker type	V, VI	V, VI	IV, V, VI	II–VI	AO classification	AO classification	I–VI
Time to surgery (days)	3.85	NM	NM	7	3	NM	2
Fixator period	18.37 weeks	115 days	16 weeks (type IV)18 weeks (types V and VI)	26.6 weeks	3.5 months	18.2 weeks	11–12 weeks
Follow-up	8.52 years	21 months	23 months	NM	30 months	30 months	12 months
Extension lag	0	0	NM	5	0	2	27
Mean flexion range	122.78°	119°	10°–20° <full ROM	NM	112°	112°	140° (types I–IV) 120° (types V and VI)
Deep vein thrombosis	1	2	3	0	0	1	1
Deep infection	0	0	3	2	0	0	0
Articular depression>4 mm	3	NM	NM	NM	3	2	3
Angular deformity>7°	1	NM	3	2	3	2	3
Outcome assessment	ASAMI score	ASAMI score	Karlstrom-Olerud scoring	Lyshom's scoreHohl and Luck score	ASAMI score	Iowa knee scoreRasmussen score	Rasmussen scoreKOOS

KOOS, Osteoarthritis Outcome Score; NM, not mentioned; ROM, range of motion.

Parameswaran *et al.* [24] reported that ring fixators had the lowest incidence of infection compared with the hybrid external and unilateral fixators. Using the Ilizarov technique, Catagni *et al.* [1] did not observe any deep infections in a series of 59 patients with Schatzker V–VI fractures. An important advantage of Ilizarov technique is that it is essentially a closed method, and if the surgical time extends, the risk of wound contamination is low when compared with open plating in the tibial plateau [2,25].

On using ASAMI scoring, the results were good to excellent in 23 (85.2%) patients. There is no consensus on which knee score is best for patient follow-up studies for tibial plateau fractures [9]. Also, the diversity of scores used makes meaningful comparisons between the studies difficult (Table 2). Catagni *et al.* [1] reported good to excellent results in 57 of 59 patients. Ali [4] reported that in 20 of 25 cases.

This study, in contrast to many studies, has a relatively long-term follow-up with a mean of 8.5 years, included a homogeneous group of patients with complex fractures of the tibial plateau treated by one protocol, and reported for the first time the use of gradual skin traction for assisting wound closure in open tibial plateau fractures. The limitations of the study include the retrospective nature of the study, lack of a control group, and the relatively small number of patients.

Conclusion

The Ilizarov fixator can be considered as the treatment of choice for complex tibial plateau fractures, particularly when extensive dissection and internal fixation are contraindicated. Adequate debridement, stable fixation, fixation across the knee when necessary, proper wound care, and early and programmed rehabilitation are points worthy of emphasis. Soft-tissue traction was helpful in wound closure.

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Conflicts of interest

There are no conflicts of interest.

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