



Original Article

Outcome of complex tibial plateau fractures with Ilizarov external fixation with or without minimal internal fixation

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ABSTRACT

Purpose: To evaluate the clinico-radiological outcome of complex tibial plateau fractures treated with Ilizarov external fixation with or without minimal internal fixation.

Methods: This retrospective review was conducted on all the cases of Schatzker types V and VI tibial plateau fractures treated by Ilizarov external fixation between July 2006 and December 2015 with the minimum follow-up duration of one year. There were 30 patients: 24 males and 6 females, mean age 43.33 years, and mean follow-up 3.6 years. Three of them were open fractures; 15 cases were Schatzkertype V fractures and the other 15 type VI. According to AO/OTA classification, there were 11 type C1, 12 C2 and 7 type C3 fractures. Outcome assessment was made with American Knee Society Score (AKSS) and Rasmussen's Radiological Score (RRS) at final follow-up.

Results: Out of the 30 cases, mini-open reduction was performed in 7, bone graft in 4, minimal internal fixation in 10 and knee temporary immobilisation in 11 patients. Mean duration of external fixation was 11.8 weeks. All fractures united. Pin tract infections in 7 and common peroneal neuropathy in 2 patients were self-limiting. Two patients had axial misalignment of less than 10°. At final follow-up, the mean knee range of motion was 114.7, mean AKSS 81.5 and mean RRS 16.7. On statistical analysis, Schatzker type of fractures, use of minimal internal fixation and knee-spanning did not influence the final outcome.

Conclusion: Ilizarov external fixator with or without minimal internal fixation provides acceptable outcome for complex tibial plateau fractures. Care must be taken to look for minor loss of alignment, especially in Type VI Schatzker fractures after removal of the fixator. However small sample size precludes firm conclusions.

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Introduction

Complex tibial plateau fractures are considered a challenging surgical problem.¹ The challenges are due to fracture pattern (articular depression, condylar comminution, diaphyseal involvement), associated soft tissue and ligament injuries, associated neurovascular damage and compartment syndrome.² Failure to restore articular congruity and presence of ligamentous instability are the most important factors causing poor outcome in a long term.³ Success depends on restoration of articular cartilage,

preservation of biology, alignment of mechanical axis, restoration of joint stability and preservation of functional motion.⁴

Nonoperative management yields poor results and internal fixation has its own complications like wound break-down, skin necrosis, deep infections, stiffness and ankylosis depending on the extent of injury and surgery leading to multiple debridements, arthrodesis and even amputation.^{5,6} The advent of minimally invasive techniques of internal fixation could not solve this challenge completely.⁷

Ilizarov external fixation is an attractive treatment option to address all treatment goals. The merits of Ilizarov are: closed or mini-open fracture reduction with less chance of wound complications; early joint motion, functional loading and weight bearing; possibility to improve reduction and alignment while on fixator and faster return to function. Even if knee replacement is needed for arthritis in future, it will be technically easier than with internal

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fixation as surgery does not use extensive incisions, compromise with soft tissue cover or introduce significant hardware inside. A well designed, multi-centre, prospective randomised trial comparing internal fixation and Ilizarov external fixation for complex tibial plateau fractures concluded that the number and severity of complications are higher with open reduction and internal fixation; Ilizarov external fixation results in shorter hospital stay and a marginally faster return of function.⁸

We hypothesised that Ilizarov external fixation with or without minimal internal fixation is an attractive option for treatment of complex tibial plateau fractures and performed a retrospective evaluation of our patients for clinico-radiological outcome and complications.

Methods

This is a retrospective study (after approval of the Institutional Ethics Committee) of all cases of complex tibial plateau fractures treated with Ilizarov external fixation with or without minimal internal fixation between July 2006 and December 2015. The inclusion criteria were skeletally mature patients less than 60 years old, closed and open Schatzker type V or VI tibial plateau fractures, surgery within one week of injury, follow-up of at least one year from removal of external fixator, and complete availability of clinico-radiological records. Patients associated with neurovascular injuries, presence of other fractures or systemic injuries, underwent damage control measures like fasciotomy or temporary spanning external fixation, and with fixation modalities other than Ilizarov were excluded.

During the study period, 102 tibial plateau fractures were treated surgically in our department. Among them 64 were type V or VI Schatzker fractures. Out of this, 37 patients were treated with Ilizarov external fixation, the decision being based on the fracture pattern, soft tissue condition, surgeon preference and patient acceptance. These patients were followed-up once in a week till removal of fixator, 3–4 weeks from removal of fixator, once in three months for the next 12 months and yearly thereafter. Data was collected from all clinical notes and radiographs of these patients. Among them 7 cases were excluded due to lack of one year follow-up and thus 30 patients were included in the study. Complete clinico-radiological data was available for all thirty patients.

All patients reporting with Schatzker types V or VI fractures were admitted after documenting the distal neurovascular status. Preliminary wound debridement and wound coverage if feasible were done for open fractures and were started on antibiotics according to protocol for open fractures. Patients were put on limb elevation, splinting and anti-edema measures. Orthogonal radiographs were obtained for all cases and CT scan was performed in selected cases. We performed surgical stabilisation in all cases at the earliest opportunity after optimising skin condition and fitness for anaesthesia.

All cases were operated under spinal anaesthesia. Indirect reduction was achieved with calcaneal traction in fracture table or femoral distractor in radioluscent table with knee at desired degrees of flexion under radiological control. If needed, open reduction was performed with small incisions and clamps were application. In cases with persisting condylar depression, the joint line was elevated through a metaphyseal window with application of cortico-cancellous bone graft from ipsilateral iliac crest. In selected cases, 7 mm cannulated cancellous screws (CCS) were used to maintain reduction of fragments. Ilizarov apparatus was assembled over this with the first ring in the juxta-articular region of tibia, second ring just below the fracture site and third ring in the supramalleolar region. Tensioned olive wires were used to hold fracture reduction; non-olive wires were used in the rest of

segments; and a few cases had 5 mm Schanz screws applied to diaphyseal segments according to surgeon's preference. Cases with severe articular comminution or ligamentous instability had their knees spanned with a single distal femoral ring for a period of 4–6 weeks.

All patients with below-knee constructs were encouraged to mobilise their knees as much as the fixator would permit. All patients with spanning external fixators were made to full weight-bearing with crutches as per tolerance immediately after surgery and those with non-spanning fixators were made to partial weight-bearing and progress as tolerated. Patients were followed-up clinically every week for pin tract infections; axial alignment and radiological assessment was done once in 4 weeks. The decision to remove fixator was taken after evidence of bridging in two orthogonal views and satisfactory stress test after removal of rods between the first two rings. The limbs were protected in a removable brace during weight bearing for 3–5 weeks after removal of fixator, depending on the findings at stress test. The patients were permitted only partial weight bearing during this period.

At every subsequent visit, patients were evaluated for pain, knee and ankle range of motion (ROM), limb alignment, instability or pain at stress tests, radiological assessment of fracture union, alignment, occurrence of arthritis and functional status. Objective assessments were made with American Knee Society Score (AKSS) and Rasmussen's Radiological Score (RRS).^{9,10} AKSS is a physician evaluated score based on pain (maximum 50 points), knee stability (maximum 25 points) and ROM (maximum 25 points), all adding up to 100 points with appropriate deductions for flexion contracture, extensor lag and malalignment. Based on AKSS, the outcome is rated as excellent (≥ 85), good (75–84), fair (60–74) and poor (< 60). RRS evaluates articular depression, intercondylar widening and metadiaphyseal angulation, each having a maximum score of 6 and a minimum of 0, making it a total of 18.

All continuous variables were presented as mean (SD, range) or median (interquartile range) if not normally distributed (assessed by D'Agostino-Pearson test) and proportions. The independent sample *t*-test with appropriate correction (Welch) was used for data analysis of two groups of continuous variables with level of significance decided beforehand at $p < 0.05$ with two tail distribution. Kruskal-Wallis test was used to evaluate co-variance among more than two groups of independent samples for non-parametric data. All calculations were done using MedCalc V15.8 (Ostend, Belgium).

The mean age of the study group was 43.33 (25–58) years consisting of 24 males and 6 females. Left side was involved in 18 patients and right in 12. The mechanism of injury was road traffic accident in 15, fall from height in 12 and other causes in 3 patients. The fractures were closed in 27 patients, open in 3 out of which 2 were Gustilo Andersen grade I and one grade IIIA. There were 15 Schatzker type V and 15 type VI fractures. Based on AO/OTA classification, 11 fractures were classified as type C1, 12 type C2 and 7 type C3. Twenty-three patients presented immediately after injury, whereas seven reported late.

Results

The mean interval between injury and surgery was 4 (1–7) days. The mean operating time was 2.5 (2–3.5) h. Mean hospital stay was 6 (2–16) days. Closed reduction could be achieved in 23 cases; small incisions were used for open reduction in the rest 7 cases. Four cases had bone graft for elevation of joint line and 10 cases had minimal internal fixation with 7 mm CCS. Eleven cases had their frame extended to distal femur and retained for a period of 4–6 weeks, to account for fracture instability or ligament injury.

Seven patients started immediate weight bearing. All patients could be made to full weight bearing at a mean of 5.3 (0–20) weeks. Seven patients developed pin tract infections. Five of them settled with oral antibiotics and regular dressings. Two patients need exchange of wires under anaesthesia. Two patients developed common peroneal neuropraxia following surgery. Both of them did not

have any associated fracture of the proximal fibula. This could be related to closed manipulation or pin placement through fibular head. Both of them recovered completely prior to removal of external fixator. Though neuropathy affected immediate post-operative rehabilitation of the two patients, both patients recovered without any permanent deficits.



Fig. 1. A 47-year-old male patient with type V Schatzker fracture of the left tibia. (A, B) Preoperative anteroposterior and lateral radiographs; (C, D) Immediate postoperative anteroposterior and lateral radiographs; (E–G) Rehabilitation with external fixator after knee mobilization; (H) Anteroposterior and lateral radiographs at external fixator removal; (I–K) Clinical photographs at final follow-up showing limb alignment and function.

All fractures united. There was no incidence of septic arthritis or deep vein thrombosis. Two patients with type VI Schatzker fractures showed malalignment of less than 10° in follow-up X-rays. Retrospectively it was found that the loss of alignment happened within a few weeks after removal of fixator. The fixators remained for a mean of 11.8 (7–16) weeks, followed by a period of bracing and protected weight bearing in all cases. There were no cases of ligamentous instability noted after removal of frame and none of the patients underwent any further investigation in this regard. There was no case of re-fracture following fixator removal.

The mean follow-up from removal of fixator was 3.6 years (13–87 months). Three patients reported pain of variable severity. The mean ROM of knee at final follow-up was 114.7° (100° – 150°). The mean AKSS at final follow-up was 81.5 (56–93). As per rating, 16 had excellent outcome, 8 had good, 5 had fair and 1 had poor outcome. The mean RRS was 16.7 (14–18). Thirteen patients scored 18, 11 scored 14 and 3 scored 14 in RRS (Figs. 1 and 2).

The use of minimal internal fixation did not affect the final clinico-radiological outcome (Table 1) and spanning the knee did not affect the final knee ROM or functional score (Table 2). This means that opposing olive wires and cancellous screws are equally effective in holding the fragments together and surgeon can use minimal internal fixation according to clinical situation and convenience. Also the surgeon must not hesitate to extend the fixator above knee for brief periods whenever required as it does not affect the final outcome. Also there was no difference in clinico-radiological outcome among the two Schatzker types or three AO/OTA types (Table 3).

Discussion

Bicondylar tibial plateau fractures pose a great challenge to treatment. Ilizarov external fixation has evolved as an attractive

Table 1

Clinico-radiological outcome of patients with and without minimal internal fixation (mean \pm SD).

Minimal internal fixation	RRS	AKSS
used ($n = 10$)	16.8 ± 1.7	83.9 ± 7.1
Not used ($n = 20$)	16.6 ± 1.3	80.3 ± 10.5
<i>p</i> value	0.72	0.33

RRS: Rasmussen's Radiological Score; AKSS: American Knee Society Score.

Table 2

Knee ROM and functional outcome in patients where knee was spanned and not spanned (mean \pm SD).

Knee	Knee ROM ($^\circ$)	AKSS
Spanned ($n = 11$)	113.6 ± 6.7	83.1 ± 8.1
Not spanned ($n = 19$)	115.3 ± 16.8	80.5 ± 10.4
<i>p</i> value	0.71 (Welch corrected)	0.49

ROM: Range of motion; AKSS: American Knee Society Score.

Table 3

Clinico-radiological outcome of Schatzker type V and VI fractures.

Fracture type	RRS	<i>p</i> value	AKSS	<i>p</i> value
Schatzker type ^a		0.13		0.31
V ($n = 15$)	17.1 ± 1.3		83.3 ± 8.0	
VI ($n = 15$)	16.3 ± 1.5		79.7 ± 10.9	
AO/OTA type ^b		0.86		0.99
C1	18 (14.5–18)		87 (76.5–88.75)	
C2	17 (16–18)		85 (73.5–88.5)	
C3	16 (16–17.5)		87 (76.5–88.5)	

RRS: Rasmussen's Radiological Score; AKSS: American Knee Society Score.

^a Data are expressed as mean \pm SD.

^b Data are expressed as median (interquartile range).



Fig. 2. A 31-year-old male patient with type VI Schatzker fracture of left tibia. (A, B) Preoperative anteroposterior and lateral radiographs; (C, D) Immediate postoperative anteroposterior and lateral radiographs; (E) Three year follow-up X-rays; (F–G) Limb alignment and clinical function at final follow up.

option in the treatment of these fractures. Based on previous facts, we reviewed our results to examine the role of Ilizarov in these difficult-to-treat fractures.

The biggest advantage of Ilizarov fixation is probably the ability to stably reduce and stabilise the fracture with minimum or no soft tissue dissection in an already compromised soft tissue environment. Ring construct with tensioned wires provide more mechanical stability and superior metadiaphyseal purchase and support, compared to conventional external fixators. Tensioned wires provide good purchase in soft cancellous bone. They act as a scaffold in buttressing the subchondral bone preventing collapse, restore the intrinsic stability of the fracture site with a bridging device, and allow the patient to transfer his or her weight through this flexible scaffold to the distal diaphysis, bypassing the comminuted area and permitting early joint movement and weight bearing while maintaining reduction.¹¹ It is noteworthy that adding mini-open reduction, bone graft, minimal internal fixation, and brief period of knee immobilisation— all make the procedure technically easier without compromising the final outcome.

Our results and complications are comparable to those of other authors who have treated Type V and VI Schatzker tibial plateau fractures with Ilizarov (Table 4).^{1,2,12–19} It can be observed that mini-open reduction,^{1,2,12,13,15} minimal internal fixation,^{1,13,15,18,19} bone graft^{1,12,19} and temporary knee immobilisation^{1,2,13,15,18,19}

were used by many authors when performing Ilizarov external fixation. The results of open reduction and internal fixation in Type V and VI Schatzker tibial plateau fractures are summarised in Table 5.^{20–28} Though the data is not objectively comparable due to lack of homogeneity between various studies, it can be inferred from Tables 4 and 5 that internal fixation is associated with more number and frequency of complications.

This study has numerous limitations. First, this is a retrospective study of available medical records. We did not assess the patients directly. Seven patients were excluded owing to lack of required follow-up; this potentially could have biased the results. There could be assessment bias as the surgeons documented the post-operative assessment of their own work. We did not follow any strict criteria to offer Ilizarov as a treatment for Type V and VI Schatzker fractures, this could have led to selection bias. Also the patients need longer follow-up to monitor for arthritic changes. Finally the lack of control group limits us from making firm conclusions about the results of Ilizarov fixation in these types of fractures.

We conclude that Ilizarov external fixator with or without minimal internal fixation provides acceptable outcome in complex tibial plateau fractures. Care must be taken to look for minor loss of alignment especially in Type VI Schatzker fractures after removal of fixator. However given the small number of cases in this study, we cannot offer firm conclusions.

Table 4

Outcome and complications of Ilizarov osteosynthesis in Schatzker type V and VI fractures available in the literature.

Patient cohort	Case No./open fractures	MFU (month)	Union rate (%)	Complications and incidence
Dendrinos et al. ²	24/–	36.5	100	1 delayed union, 4 DVT, 4 DVT + PE
Kumar et al. ¹²	57/22	42	93	3 malunion, 1 nonunion, 4 osteomyelitis, 3 patients needed amputations due to infections, not related to fixation
Kastenis et al. ¹³	48/18	38	98	1 CPN palsy, 6 DVT, 1 PTI, 1 stiff knee, 4 malunion, 1 infected nonunion
Barbary et al. ¹	30/–	27	100	None except for minor PTI
Kataria et al. ¹⁴	32/4	32	100	2 superficial SSI, 3 PTI, 4 CPN palsy
Catagni et al. ¹⁵	59/5	21	100	2 CPN palsy, 2 DVT
Ferreira et al. ¹⁶	11/3	–	100	Nil
Khan et al. ¹⁷	22/1	24 ^a	95	1 DVT, 1 delayed union, 1 nonunion
Ali et al. ¹⁸	25/25	30	100	1 skin gaping, 5 PTI, 1 deep SSI
Ferreira et al. ¹⁹	46/5	15	100	None

“–” means unstated.

MFU: mean follow-up; DVT: deep vein thrombosis; PE: pulmonary embolism; CPN: common peroneal nerve; PTI: pin tract infection; SSI: surgical site infection.

^a The minimum follow-up period.

Table 5

Outcome and complications of internal fixation in Schatzker type V and VI fractures available in the literature.

Patient cohort	Case No./open fractures	MFU (month)	Union rate (%)	Complications
Barei et al. ²⁰	83/11	35	99	1 nonunion, 2 heterotopic ossification, 4 stiff knee, 1 equinus contracture, 16 implant removal due to symptoms, 16 DVT, 8 superficial SSI, 7 deep SSI
Yu et al. ²¹	44/–	23.7	100	9 stiff knee, 3 varus malalignment, 2 valgus malalignment, 2 deep SSI, 1 delayed union, 10 secondary arthritis
Zhang et al. ²²	79/–	27.4	100	3 deep SSI, 7 loss of reduction, 3 loss of alignment, 10 knee instability, 17 early arthritis
Cho et al. ²³	10/–	33.7	100	1 delayed wound healing
Prasad et al. ²⁴	46/1	4 years	100	4 extensor lag, 4 loss of articular reduction, 1 compartment syndrome postoperative, 1 skin necrosis, 1 delayed wound healing, 1 valgus malalignment, 1 transient CPN palsy, 3 persistent ACL laxity
Khatri et al. ²⁵	65/–	32	98	2 delayed union, 1 nonunion, 9 superficial SSI, 3 deep SSI, 1 osteomyelitis
Ruffolo et al. ²⁶	140/–	64 weeks	93	4 superficial SSI, 23 deep SSI, 10 nonunion, 6 stiff knee, 1 varus malunion, 7 implant removal due to pain, 3 DVT, 2 pulmonary embolism, 10 flexion contracture of knee
Rohra et al. ²⁷	34/–	3 years ^a	100	3 knee stiffness, 2 superficial SSI, 1 extensor lag
Unno et al. ²⁸	102/–	1 year ^a	99	9 SSI, 3 postoperative compartment syndrome, 1 nonunion, 2 fixation failure, 3 implant removal due to discomfort

“–” means unstated.

MFU: mean follow-up; DVT: deep vein thrombosis; SSI: surgical site infection; CPN: common peroneal nerve; ACL: anterior cruciate ligament.

^a The minimum follow-up period.

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Ethical statement

This study has been approved by the Institutional Ethics Committee.

Conflicts of interest

All authors declare that they have no conflict of interests.

References

- El Barbary H, Abdel Ghani H, Misbah H, et al. Complex tibial plateau fractures treated with Ilizarov external fixator with or without minimal internal fixation. *Int Orthop*. 2005;29:182–185. <https://doi.org/10.1007/s00264-005-0638-6>.
- Dendrinios GK, Kontos S, Katsenis D, et al. Treatment of high-energy tibial plateau fractures by the Ilizarov circular fixator. *J Bone Joint Surg Br*. 1996;78:710–717.
- Lansinger O, Bergman B, Körner L, et al. Tibial condylar fractures. A twenty-year follow-up. *J Bone Joint Surg Am*. 1986;68:13–19.
- John KS, Bret K. Wire ring fixation of complex tibial plateau fractures. In: Rozbruch SR, Ilizarov S, eds. *Limb Lengthening and Reconstruction Surgery*. New York: Informa Health Care; 2007:79–96.
- DeCoster TA, Nepola JV, el-Khoury GY. Cast brace treatment of proximal tibia fractures. A ten-year follow-up study. *Clin Orthop Relat Res*. 1998;231:196–204.
- Young MJ, Barrack RL. Complications of internal fixation of tibial plateau fractures. *Orthop Rev*. 1994;23:149–154.
- Ozkaya U, Parmaksizoglu AS. Dual locked plating of unstable bicondylar tibial plateau fractures. *Injury*. 2015;46(suppl 2):S9–S13. <https://doi.org/10.1016/j.injury.2015.05.025>.
- Canadian Orthopaedic Trauma society. Open reduction and internal fixation compared with circular fixator application for bicondylar tibial plateau fractures. *J Bone Joint Surg Am*. 2009;91(suppl 2 Pt 1):74–88. <https://doi.org/10.2106/JBJS.G.01165>.
- Insall JN, Dorr LD, Scott RD, et al. Rationale of the knee society clinical rating system. *Clin Orthop Relat Res*. 1989;248:13–14.
- Ozturkmen Y, Caniklioglu M, Karamehmetoglu M, et al. Calcium phosphate cement augmentation in the treatment of depressed tibial plateau fractures with open reduction and internal fixation. *Acta Orthop Traumatol Turc*. 2010;44:262–269. <https://doi.org/10.3944/AOTT.2010.2406>.
- Ali AM, Burton M, Hashmi M, et al. Outcome of complex fractures of the tibial plateau treated with a beam-loading ring fixation system. *J Bone Joint Surg Br*. 2003;85:691–699.
- Kumar A, White AP. Treatment of complex (Schatzker type VI) fractures of the tibial plateau with circular wire external fixation: retrospective case review. *J Orthop Trauma*. 2000;14:339–344.
- Katsenis D, Athanasiou V, Megas P, et al. Minimal internal fixation augmented by small wire transfixion frames for high-energy tibial plateau fractures. *J Orthop Trauma*. 2005;19:241–248.
- Kataria H, Sharma N, Kanojia RK. Small wire external fixation for high-energy tibial plateau fractures. *J Orthop Surg (Hong Kong)*. 2007;15:137–143. <https://doi.org/10.1177/230949900701500202>.
- Catagni MA, Ottaviani G, Maggioni M. Treatment strategies for complex fractures of the tibial plateau with external circular fixation and limited internal fixation. *J Trauma*. 2007;63:1043–1053. <https://doi.org/10.1097/TA.0b013e3181238d88>.
- Ferreira N, Senoge ME. Functional outcome of bicondylar tibial plateau fractures treated with the Ilizarov circular external fixator. *SA Orthop J*. 2011;10:80–84.
- Muhammad AK, Muhammad IK, Muhammad S. Management of complex tibial plateau fractures with Ilizarov fixator. *Pak J Surg*. 2012;28:110–113.
- Ali AM. Outcomes of open bicondylar tibial plateau fractures treated with Ilizarov external fixator with or without minimal internal fixation. *Eur J Orthop Surg Traumatol*. 2013;23:349–355. <https://doi.org/10.1007/s00590-012-0989-9>.
- Ferreira N, Marais LC. Bicondylar tibial plateau fractures treated with fine-wire circular external fixation. *Strat Trauma Limb Reconstr*. 2014;9:25–32. <https://doi.org/10.1007/s11751-014-0185-z>.
- Barei DP, Nork SE, Mills WJ, et al. Complications associated with internal fixation of high-energy bicondylar tibial plateau fractures utilizing a two-incision technique. *J Orthop Trauma*. 2004;18:649–657.
- Yu Z, Zheng L, Zhang Y, et al. Functional and radiological evaluations of high-energy tibial plateau fractures treated with double-butress plate fixation. *Eur J Med Res*. 2009;14:200–205. <https://doi.org/10.1186/2047-783X-14-5-200>.
- Zhang Y, Fan DG, Ma BA, et al. Treatment of complicated tibial plateau fractures with dual plating via a 2-incision technique. *Orthopedics*. 2012;35:e359–e364. <https://doi.org/10.3928/01477447-20120222-27>.
- Cho KY, Oh HS, Yoo JH, et al. Treatment of Schatzker type V and VI tibial plateau fractures using a midline longitudinal incision and dual plating. *Knee Surg Relat Res*. 2013;25:77–83. <https://doi.org/10.5792/ksrr.2013.25.2.77>.
- Prasad GT, Kumar TS, Kumar RK, et al. Functional outcome of Schatzker type V and VI tibial plateau fractures treated with dual plates. *Indian J Orthop*. 2013;47:188–194. <https://doi.org/10.4103/0019-5413.108915>.
- Khatri K, Sharma V, Goyal D, et al. Complications in the management of closed high-energy proximal tibial plateau fractures. *Chin J Traumatol*. 2016;19:342–347. <https://doi.org/10.1016/j.cjtee.2016.08.002>.
- Ruffolo MR, Gettys FK, Montijo HE, et al. Complications of high-energy bicondylar tibial plateau fractures treated with dual plating through 2 incisions. *J Orthop Trauma*. 2015;29:85–90. <https://doi.org/10.1097/BOT.0000000000000203>.
- Rohra N, Suri HS, Gangrade K. Functional and radiological outcome of Schatzker type V and VI tibial plateau fracture treatment with dual plates with minimum 3 years follow-up: a prospective study. *J Clin Diagn Res*. 2016;10:RC05–RC10. <https://doi.org/10.7860/JCDR/2016/18732.7855>.
- Unno F, Lefavre KA, Osterhoff G, et al. Is early definitive fixation of bicondylar tibial plateau fractures safe? An observational cohort study. *J Orthop Trauma*. 2017;31:151–157. <https://doi.org/10.1097/BOT.0000000000000779>.