






# Ilizarov Ring External Fixation for Complex Tibial Plateau Fractures

## *Fixação externa do anel de Ilizarov para fraturas complexas do platô tibial*

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### Abstract

**Objective** To analyze the results of clinical, radiological, and functional outcomes of tibial plateau fracture (Schatzker Type V, VI) treated with Ilizarov ring external fixator with or without minimum opening.

**Methods** A total of 52 tibial plateau fractures of type V, VI were treated with Ilizarov ring external fixator with or without minimum internal fixation were studied. Functional outcome assessment was done using the American Knee Society (AKS) score with clinical, radiological union, and complications were analyzed.

**Results** There were 37 (71.15%) male and 15 (28.84%) female patients, with a mean age of  $39.07 \pm 12.58$  years old. Road traffic accidents (RTAs) were the major cause of fracture, accounting for 32 cases (61.53%) followed by fall injury, with 16 cases (30.76%), and direct impact, with 4 cases (7.69%). Twenty-one (40.38%) cases were type V and 31 (59.61%) cases were type VI fractures, and there were 24 (46.15%) cases of open fracture. The mean AKS score of Type V and Type VI fractures were 82.8 and 80.70, respectively, but this was statistically not significant at  $p < 0.05$ . The mean AKS score of closed and open fractures were also statistically not significant at  $p < 0.05$ .

**Conclusions** For Schatzker Types V and VI complex tibial plateau fractures, Ilizarov external fixation is a safe, cost-effective and efficient treatment method that presents a satisfactory outcome.

### Keywords

- ▶ Ilizarov technique
- ▶ external fixator
- ▶ tibial fracture
- ▶ Schatzker classification

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**Resumo**

**Objetivo** Analisar os resultados clínicos, radiológicos e funcionais da fratura do planalto tibial (Schatzker Tipo V, VI) tratada com fixador externo do anel Ilizarov com ou sem abertura mínima.

**Métodos** Um total de 52 fraturas do planalto tibial dos tipos V e VI foram tratadas com fixador externo do anel Ilizarov com ou sem fixação interna mínima. A avaliação do desfecho funcional foi feita utilizando-se o escore da American Knee Society (AKS, na sigla em inglês) com consolidação clínica, radiológica e complicações encontradas.

**Resultados** Foram 37 (71,15%) pacientes do sexo masculino e 15 (28,84%) do sexo feminino, com idade média de  $39,07 \pm 12,58$  anos. Acidentes de trânsito (ATs) foram a principal causa das fraturas, contabilizando 32 casos (61,53%), seguidos por lesão por queda, com 16 casos (30,76%), e impacto direto, com 4 casos (7,69%). Foram 21 (40,38%) casos de fraturas tipo V, 31 (59,61%) casos do tipo VI e 24 (46,15%) casos de fratura exposta. Os escores médios da AKS para as fraturas tipo V e VI foram de 82,8 e 80,70, respectivamente, mas não foi estatisticamente significativo em  $p < 0,05$ . O escore médio da AKS para fraturas fechadas e abertas também não foi estatisticamente significativo em  $p < 0,05$ .

**Conclusões** Para a fratura do planalto tibial complexa dos tipos V e VI de Schatzker, a fixação externa de Ilizarov é um método de tratamento seguro, econômico e eficiente que resulta em resultados satisfatórios.

**Palavras-chave**

- técnica de Ilizarov
- fixadores externos
- fraturas da tibia
- classificação de Schatzker

**Introduction**

Tibial plateau fractures are complex injuries and one of the most difficult and controversial tasks for the management.<sup>1</sup> Schatzker et al.<sup>2</sup> classified these fractures into six types, and types V, VI are generally caused by high energy injuries. The most commonly encountered problems of these fractures are condylar comminution, articular depression, diaphyseal involvement, severe soft tissue injury, neurovascular damage, ligamentous injuries, and acute compartment syndrome, and these problems are directly related to the surgical decision-making and prognosis.<sup>3</sup> While managing, unable to restore the articular congruency and the presence of severe soft tissue injuries are the culprits for poor outcomes.<sup>4</sup> The aim of the management are restoration of the articular congruency, preservation of the bone biology, reestablishment of the mechanical axis, restoration of the joint stability, and preservation of movement.<sup>5</sup> Conservative management results in poor outcome, and the open method has complications like skin necrosis, high chance of wound infections, joint stiffness, and, sometimes, even multiple debridement, arthrodesis and amputation are needed.<sup>6</sup> The development of the less invasive stabilization system (LISS) and minimally invasive plating techniques also could not solve these problems.<sup>7</sup> In the literature, there is no consensus of a particular method for the management of these fractures.

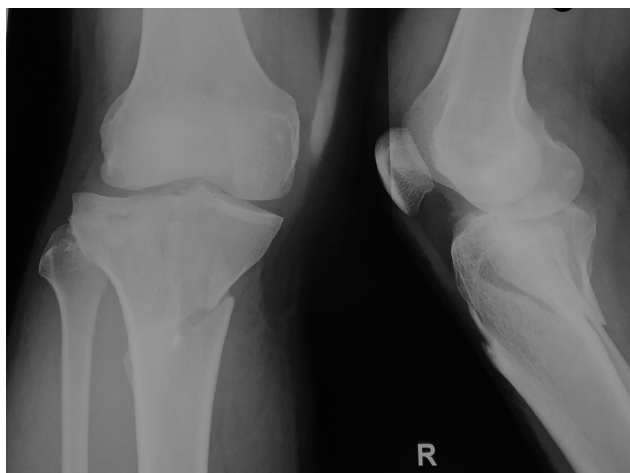
The Ilizarov technique is a concept of indirect fracture reduction with biological fixation resulting in the satisfactory outcome of complex proximal tibial fractures that also includes the concept of spanning of the knee joint.<sup>8</sup> In this technique, the fractures are generally reduced closely by traction or by the indirect method and reduction is main-

tained by either external fixation or internal fixation before a knee spanning external fixator is applied.<sup>9</sup>

The Ilizarov external fixator ring technique is one of the options to address complex proximal tibial fractures with severe soft tissue injuries.<sup>10</sup> The merits of this technique are: closed or mini-open fracture reduction that diminishes the chance of wound and soft tissue complications; early functional loading and weight bearing; easy to adjust the alignment while on fixator and early return of joint function and technically easier than other internal fixator for the knee replacement, if needed, for post-traumatic arthritis in the future.<sup>11</sup> The aim of the present study was to evaluate the radiological, clinical, and functional outcomes of Schatzker Types V and VI tibial plateau fractures managed by Ilizarov external fixation ring.

**Materials and Methods**

The present retrospective study was conducted at the Department of Orthopedics and Trauma Surgery of our institution and was approved by the Institutional Review Committee (number 103/076-77). From January 2013 to December 2017, a total of 52 Schatzker types V and VI tibial plateau fractures that were managed with Ilizarov fixator with or without minimum internal fixation (mini-ORIF) were analyzed. The inclusion criteria were patients > 18 and < 65 years old, closed and open Schatzker type V and VI tibial plateau fractures, operation performed within 10 days of the injury, follow-up time of at least 1 year after the removal of the Ilizarov fixator. The exclusion criteria were patients < 18 and > 65 years old, patients associated with neurovascular injuries, poly trauma, associated head



**Fig. 1** Radiographs of anterior-posterior (AP) and lateral view of Type VI fracture of a 44-year-old man.

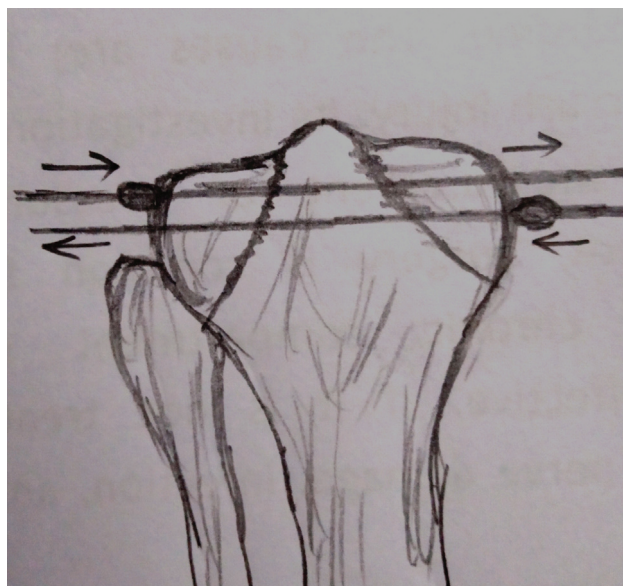
injury, who underwent fasciotomy or previous application of another temporary external fixator. Above knee plaster of Paris (POP) back slab was applied on every case, with proper elevation of the limb, before performing surgery. Primary wound irrigation and wound coverage, if possible, were done for all open fractures in the emergency room with intravenous (IV) antibiotics. The operation was performed at the earliest available operative theater schedule of the department. One of the senior surgeons evaluated and decided to apply the Ilizarov ring fixator. All data were collected from the clinical record files of the hospital (►Fig. 1).

The demographics, clinical and radiological union, malalignments and malunions, and complications encountered were collected from the medical record files and analyzed. Knee function was assessed using American Knee Society (AKS) score.<sup>12</sup> Open fractures were classified according to the Gustilo-Anderson classification.<sup>13</sup>

### Operative Technique

The operations were performed under spinal or general anesthesia on a radiolucent table under C-arm. At first, the fracture fragments were aligned by using straight manual traction, and reduction was confirmed under C-arm. The fracture fragments were held with patella-holding forceps or temporary k-wires. A bone elevator was used to elevate the fracture fragments. Depressed articular fragments of some cases needed elevation using mini-ORIF. The condition of the ligaments and menisci were inspected but not managed at this stage. Reduction of the condylar fracture fragment was performed, and counter opposed olive wires were used through the fragments to achieve interfragmentary compression (►Fig. 2). Sometimes, extra olive wires were also applied for the intraarticular stabilization. The olive wires were used for the interfragmentary compression, increasing stability of the construct and allowing gradual distraction when needed and helping in the reduction of fragments in case of translation of fragments.

Three olive wires were used in a divergent fashion of 60° to stabilize the fracture fragments and 1.8 mm olive wires



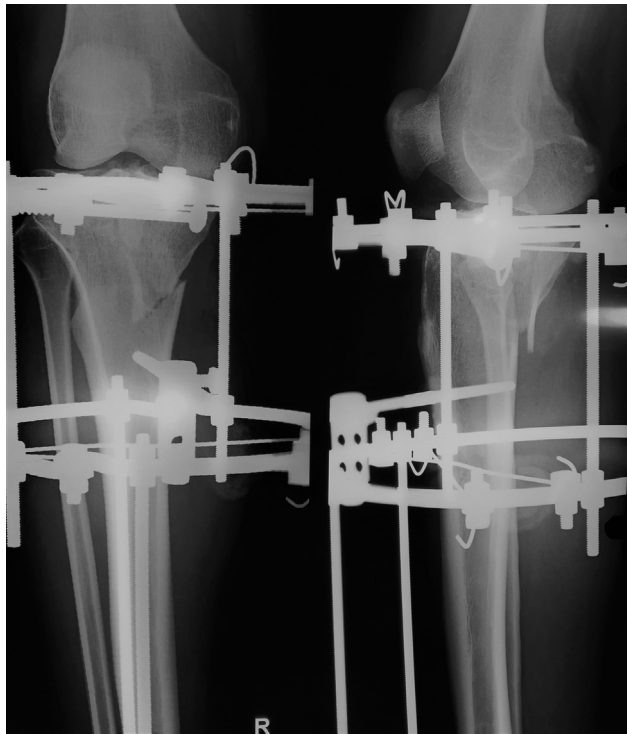
**Fig. 2** Application of olive wires for the interfragmentary compression.

were inserted from lateral to medial direction slightly anterior to the fibular head to provide interfragmentary compression. The first ring was fixed with the first wire by two fixation bolts by forming stiff compression in between the articular fragments and the other wire was applied from medial to lateral slightly distally from the ring and a drop wire was also inserted.<sup>10</sup> These rings were also linked with one ring distally by four interconnecting rods. Great care was taken to restore the mechanical axis in association with the condyles. The frame was prolonged as a distracter onto the distal end of the femur, which was fixed by two half pins between the quadriceps and the hamstring, and these femoral and tibial rings were connected by connecting rods. This was done for selected cases only when the operating surgeon felt its need to maintain the reduction (►Fig. 3).

### Postoperative Rehabilitation

Early non weight bearing (NWB) mobilization was encouraged. Active and active assisted knee range of motion (ROM), and quadriceps and other muscle strengthening exercises were taught by the physiotherapist. Toe touch walking was advised after 1 week. Regular pin tract dressing and wound inspections were done. Partial weight bearing walk to protected full weight bearing walk were started on the 4<sup>th</sup> to the 6<sup>th</sup> week postoperatively. Arrangements of the follow-ups were made on the 2<sup>nd</sup>, 4<sup>th</sup>, and 8<sup>th</sup> weeks and on the 3<sup>rd</sup>, 6<sup>th</sup>, 9<sup>th</sup>, 12<sup>th</sup>, and 16<sup>th</sup> months, and later as advised by the surgeon until at least 1 year after the removal of the ring.

Fracture union was defined as the presence of callus bridging on radiograph with no abnormal motion at the fracture site, no pain on full weight bearing and stressing at the fracture site after loosening the frame.<sup>14</sup> If the patient still had painful full weight bearing walk, then the ring was tightened again and the patient was followed-up to remove the ring when painless full weight bearing walk was achieved.



**Fig. 3** X-ray after Ilizarov fixation with minimal internal fixation.

### Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 22 (IBM Corp., Armonk, NY, USA). Quantitative data such as age, hospital stay, knee score etc. were expressed as mean  $\pm$  standard deviation (SD), while qualitative data such as gender, cause of fractures, and open fractures were expressed as a percentage. The student t-test was used for data analysis of two groups of continuous variables with a level of significance set at  $p < 0.05$  (**Table 1** and **Fig. 4**).

### Results

The total number of cases of tibial plateau fractures that were managed surgically were 112, 65 of which were type V and VI fractures. Seven patients were managed using other techniques and 58 were managed by Ilizarov ring external fixators with or without mini-ORIF. Six cases were excluded due to inadequate information in the medical records. Thus, 52 patients remained in the final study. All cases were unilateral and, among them, 37 (71.15%) were male. The mean time of follow-up was  $19.01 \pm 4.68$  months (range, 12–29 months) after frame removal. The mean age of the patients was  $39.98 \pm 13.02$  years old (range 22–65 years). Road traffic accident (RTA) was the major cause of the fractures (61.53%), followed by fall injury (30.76%). There were 24 (46.15%) cases of open fracture, 21 (40.38%) were Schatzker type V and 31 (59.61%) were Schatzker type VI fractures. Among them, 28 (53.84%) were closed and 24 (46.15%) were open fractures.

Forty-two cases were treated with 3 or 2 rings below the knee, 10 (19.23%) cases had 1 ring above the knee at the distal

femur and 2 or 3 rings below the knee. Five (9.61%) cases needed mini-ORIF with cancellous bone graft, and most cases were augmented with an additional cancellous screw or k-wires. The transknee ring fixator was removed at an average of 6.8 weeks and knee range of motion (ROM) was started.

The mean time of operation after the injury was  $4.86 \pm 2.11$  days (range, 1–10 days) and the mean hospital stay was  $9.01 \pm 2.81$  days (range, 5–20 days). The mean time of union and removal of all external rings was  $15.09 \pm 2.25$  weeks (range 12–20 weeks). The mean AKS score was  $81.65 \pm 8.52$  (range 58–9), the mean degree of knee flexion was  $110 \pm 13.22^\circ$  (range 85–130°), and the extension lag was  $-6.15 \pm 4.45^\circ$  (range 0 to -15°). The mean AKS score of Type V fractures was  $82.8 \pm 7.42$ , and of Type VI fractures was  $80.70 \pm 9.10$ . Type V fractures had a better score than Type VI, but the difference was not statistically significant ( $p = 0.2$ ). The mean AKS score of closed fractures was  $80.07 \pm 9.49$ , and of open fractures was  $83.33 \pm 6.82$ , but the difference was not statistically significant ( $p = 0.17$ ). Details of the profile of the patients are shown on **Table 1**.

Pin tract infection was found in 11 (21.15%) cases, which were managed with regular pin tract dressings, education on personal hygiene to the patient, and a short course of antibiotics. However, to manage one of the pin tract infections, the patient was admitted to the hospital and received IV antibiotics. No septic arthritis nor deep infection were encountered. Varus malalignment of  $10^\circ$  was observed in 5 cases. One (1.92%) patient got knee stiffness, and 5 (9.61%) patients had quadriceps wasting, being advised to undergo vigorous physiotherapy. After removal of the frame, six patients had meniscus or cruciate ligaments injuries and were managed by the arthroscopic unit of our team. No cases of refracture were encountered.

### Discussion

Ilizarov introduced the ring external fixator, which evolved the new understanding of bone biology.<sup>15</sup> These techniques allowed the correction of rotational, angular, and translational bony malformations as well as the restoration of limb length equality.<sup>16</sup> The Ilizarov fixators have a system that consists of many parts, allowing its application to almost any limb segment, size, and deformity.<sup>17</sup>

Complex tibial plateau fractures had a high incidence of severe complications when treated with the internal fixation technique.<sup>2,18</sup> Restoration of the articular congruity is very important, and careful treatment of the soft tissues are also important.<sup>10</sup> The major advantage of the Ilizarov external fixator is its ability to firmly reduce and hold the fracture with or without minimum soft tissue dissection.<sup>3,11</sup> Ilizarov tensioned wires purchase well on the soft subchondral bone, which acts as a framework in buttressing the cancellous bone and avoiding the collapse, reinstating the essential stability of the fracture site with a bridging maneuver, and allow the patient to transfer the weight through this flexible frame to the distal diaphysis, bypassing the comminuted area and permitting early joint movement and weight bearing while maintaining reduction.<sup>3,19</sup>

**Table 1** Detail of patient profile with clinical results

Case Number	Age	Gender	Cause of injury	Schatzker classification	Open Type	Fixator time in weeks	Knee ROM		American knee society score
							Flexion	Extension lag	
1	41	M	RTA	VI	Close	12	100	- 5	85
2	45	M	RTA	VI	Close	16	115	0	88
3	32	F	RTA	V	Close	14	125	- 10	89
4	60	F	Fall	VI	II	17	130	0	87
5	51	M	RTA	VI	Close	12	125	- 5	90
6	40	M	Fall	VI	Close	14	125	- 5	86
7	24	M	Fall	V	III A	14	120	- 5	92
8	22	M	RTA	VI	Close	15	100	- 5	86
9	32	M	RTA	VI	III A	18	125	- 5	87
10	61	M	RTA	VI	II	13	100	- 5	88
11	24	F	Fall	VI	III B	20	100	-10	89
12	33	M	RTA	V	I	14	120	0	94
13	44	M	RTA	VI	I	14	120	- 5	84
14	32	M	Fall	V	Close	12	120	0	88
15	32	M	Fall	VI	Close	12	125	- 5	87
16	32	M	RTA	V	III B	14	100	0	85
17	37	M	Fall	VI	III A	18	105	- 5	89
18	26	M	Fall	V	Close	16	90	- 5	86
19	32	M	Fall	V	Close	14	120	-10	87
20	26	M	RTA	VI	II	13	105	0	93
21	50	M	Fall	V	Close	13	125	-10	91
22	33	M	RTA	VI	II	17	125	- 5	90
23	45	M	RTA	VI	III A	15	100	- 5	87
24	65	F	Fall	VI	II	14	120	0	89
25	27	M	Direct Trauma	V	Close	20	125	- 15	88
26	32	F	Direct Trauma	V	Close	16	100	- 10	89
27	60	F	Direct Trauma	V	II	18	115	0	85
28	51	F	RTA	VI	Close	14	90	-5	85
29	40	F	RTA	V	Close	13	125	-10	75
30	24	F	Fall	VI	III B	12	90	5	77
31	22	F	RTA	V	Close	15	100	-15	78
32	32	F	RTA	V	II	16	120	5	79
33	61	F	Fall	VI	Close	17	110	-10	80
34	24	F	RTA	VI	I	19	125	0	81
35	33	F	RTA	V	Close	12	90	-15	82
36	44	M	RTA	VI	Close	14	120	- 5	83
37	32	M	Fall	V	I	13	110	- 5	82
38	32	M	RTA	V	II	16	115	- 5	77
39	32	M	RTA	V	II	14	90	-10	76
40	37	M	Fall	VI	III A	17	90	-10	75
41	62	M	RTA	VI	Close	19	100	- 5	78
42	32	M	RTA	VI	I	18	100	- 5	79

*(Continued)*

**Table 1** (Continued)

Case Number	Age	Gender	Cause of injury	Schatzker classification	Open Type	Fixator time in weeks	Knee ROM		American knee society score
							Flexion	Extension lag	
43	26	M	Fall	V	Close	14	115	- 5	83
44	50	M	RTA	VI	Close	13	125	0	60
45	33	M	RTA	VI	Close	15	100	-10	65
46	45	M	RTA	VI	II	16	125	- 5	66
47	65	M	Direct Trauma	V	Close	18	100	-10	67
48	26	F	RTA	VI	Close	12	100	-10	70
49	50	M	RTA	VI	Close	15	125	0	72
50	33	F	RTA	VI	III A	17	85	-15	73
51	45	M	RTA	V	Close	13	100	-10	66
52	65	M	RTA	VI	Close	18	90	-15	58

Abbreviations: ROM, range of motion; RTA, road traffic accident.

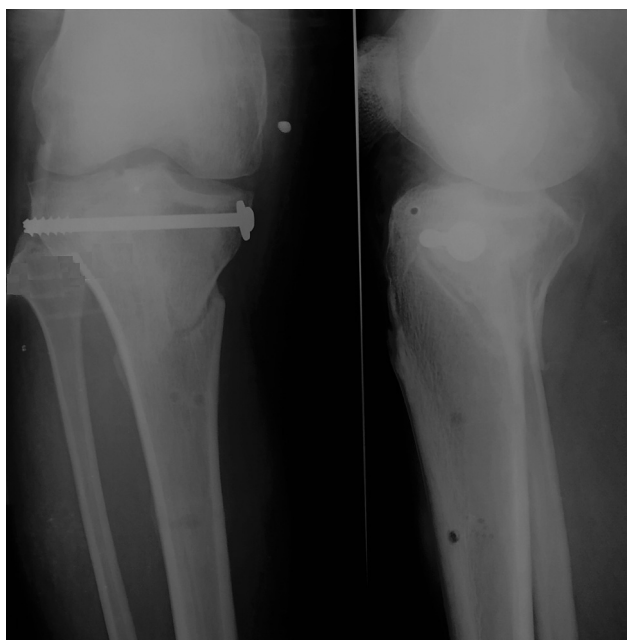
In the present study, the mean age of the patients was 39.07 years old, with a predominance of male patients. Road traffic accident was the major cause of the fractures, accounting for >60%. Ali reported that the major cause of fractures was RTA, and a predominance of males, with a mean age of 36 years old.<sup>20</sup> Other studies also reported that the major cause of the fracture was RTA with a male predominance, similar to our findings.<sup>1,3,11</sup>

The mean time of operation after the injury was 4.86 days, and the mean hospital stay was 9.01 days with a mean follow-up time of 19.01 months. Subramanyam et al.<sup>11</sup> reported that the mean time of surgery was 4 days after the injury, with a mean hospital stay of 6 days. Ali reported a mean time of surgery at 3 days postinjury, a hospital stay of

8 days, and a follow-up time of 30 months. In our study, the hospital stay, and time of operation were slightly higher but comparable with those of the aforementioned studies. In our study, 19.23% of the cases had 1 ring above the knee and 5 cases needed mini-ORIF. The mean time for the removal of all fixators after union was 15.09 weeks. Ali<sup>20</sup> reported the application of transknee ring for 30% of the cases; Subramanyam et al.<sup>11</sup> applied the trans-knee ring on 36.36% of the cases, a slightly higher percentage than ours, but Catagni et al.<sup>21</sup> reported the application of transknee ring in 67.79% of their cases. Subramanyam et al.<sup>11</sup> performed mini-ORIF on 7 cases out of a total of 30 cases in their series, El Barbary et al.<sup>1</sup> performed mini-ORIF on 6 of their 30 cases, a rate which is similar to that of the present study. But Watson et al.<sup>22</sup> reported the need of mini-ORIF for 79% of his cases, and Weiner et al.<sup>23</sup> reported the 60% of the cases required mini-ORIF. El Barbary et al.<sup>1</sup> removed the frame at an average of 16.3 weeks, and Catagni et al.<sup>21</sup> removed the frame at a mean of 115 days.

In the present study, the mean ROM of the knee flexion was 110°. Catagni et al.<sup>21</sup> reported a mean knee flexion of 119°, and Subramanyam et al.<sup>11</sup> of 114°. Our results were slightly lower. The mean AKS score of Type V fractures was better than that of Type VI, but it was not statistically significant. Subramanyam et al.<sup>11</sup> also reported the statistically not significant knee society score between type V and VI fractures. The mean AKS score of open and closed fractures was also not statistically significant.

Pin tract infections were seen on 11 (21.15%) cases, which were managed with regular pin tract dressings, and a short course of antibiotics. Catagni et al.<sup>21</sup> reported 23.73% of pin tract infection. Elsoe et al.<sup>24</sup> reported pin tract infections in 33 cases out of their total of 56 cases. These results were similar with ours. We also did not encounter deep infection nor osteomyelitis, and others also reported similar results.<sup>11,21</sup> Varus malalignment of 10° was found on 5 cases which, was also similar to the findings of other authors.<sup>1,3,11,21</sup>



**Fig. 4** Good union is seen after removal of the Ilizarov frame with cannulated cancellous screw with washer in situ.

The application of dual plating for the complex tibial plateau fractures with satisfactory results in appropriately selected cases has been reported.<sup>25,26</sup> However, Bertrand et al. reported no statistically different results between ORIF when compared with hybrid external fixation in terms of union, knee ROM, and complications.<sup>27</sup> The Canadian Orthopaedic Trauma Society also reported slightly better results of circular external fixators over internal fixators.<sup>28</sup> Zhao et al.<sup>29</sup> observed advantages of external fixators over internal fixations.

The precontoured plate of the LISS system may not be suitable for every case and it also increases the risk of implant-associated pain and infection.<sup>21,30</sup> In developing countries, these plates are also very expensive, but the Ilizarov frames are applicable multiple times, except for the wires, which also decreases the financial burden on the patient.

## Conclusion

The Ilizarov technique is one of the options for the management of complex proximal tibial fractures (Schatzker types V, VI) in which open reduction and internal fixation are not suitable because of severe comminution and soft tissue injuries. It is a safe, efficient, and soft tissue-friendly treatment modality. It allows stable fixation, early rehabilitation, early weight bearing, and care of soft tissue injuries with a comparatively lower rate of complications.

### Contributions of the Authors

Ghimire A., Devkota P. and Bhandari K. K. contributed equally to the conception and design of the work. Ghimire A. collected the data and Devkota P. and Bhandari K. K. participated on the analysis and interpretation of the data, and drafting of the manuscript for important intellectual content, and agree to be accountable for all aspects of the work related to its accuracy and integrity. Kharel Y. and Pradhan S. contributed to the conception and design of the work and the acquisition, analysis, and interpretation of the data. All authors read and approved the final manuscript.

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### Conflict of Interests

The authors have no conflict interests to declare.

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