Research Article

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Journal of Clinical & Experimental Orthopaedics
ISSN 2471-8416

2017
Vol.3 No.3:38

DOI: 10.4172/2471-8416.100038

The Effect of Trauma Severity on Clinical and Radiological Results of the Tibial Plateau Fractures Treatment

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Received date: August 04, 2017; **Accepted date:** September 15, 2017; **Published date:** September 20, 2017

Citation: Demir S, Belhan O (2017) The Effect of Trauma Severity on Clinical and Radiological Results of the Tibial Plateau Fractures Treatment. J Clin Exp Orthop .

Abstract

Background: Tibial plateau fractures, complex injuries, are observed following high- and low-energy traumas. The main goals of the treatment are to restore the extremity alignment and articular surface, and to obtain the early knee motion and rehabilitate the patient. We aimed to evaluate the effect of trauma severity on clinical and radiological results in the treatment of tibial plateau fractures.

Methods: Of 49 patients with tibial plateau fractures, 18, 16 and 15 were treated with open reduction-internal fixation, closed reduction-internal fixation, and external fixation, respectively. A total of 53.1% of patients had low-energy fractures while 46.9% of them had high-energy type. Bone union occurred in a mean of 14.4 weeks and the patients' extremities were allowed to bear full weight after bone union. Clinical and radiological results of the patients were evaluated according to Rasmussen criteria.

Results: The knee flexion motion was 128.5º in patients with low-energy fractures, while the knee flexion motion arc in high-energy fractures was detected as 97.5º. There was a statistically significant difference between two groups in terms of knee joint movement. Despite clinical outcomes in the patients with low-energy fractures were better when compared with high-energy fracture, but no statistical significance was detected. Radiological results in the patients with low-energy fractures were statistically significant better when compared with high-energy fractures.

Conclusion: Our study results suggest that the type of fracture and severity of trauma in surgical treatment of tibial plateau fractures are the main factors which affect functional and radiological results.

Keywords: Tibial plateau fractures; Treatment; Trauma severity; Results

Background

Tibial plateau fractures, which are complex injuries, are observed following high and low-energy traumas. Such fractures are frequently seen particularly in the third and fifth decade age population. Accompanied soft tissue traumas frequently affect the treatment. The main goals of the treatment are to provide restoration of extremity alignment and joint surface, and to obtain early knee motion. Open reduction and internal fixation (ORIF) are the gold standards in the treatment of these fractures. Circumferential external fixators and minimally invasive percutaneous plate osteosynthesis (MIPPO) may be preferred for the treatment of complex intraarticular fractures. Knee arthroscopy in joint fractures that can be treated with MIPPO helps both in the reduction of fracture and treatment of intra-articular soft tissue injuries [1-3].

Satisfactory clinical and functional results are obtained with low complication rates in low-energy plateau fractures [4]. However, there are various problems associated with the treatment of high-energy intra-articular tibial plateau fractures such as wound dehiscence, malalignment caused by severe fracture and varus collapse, implant failure, and knee arthritis [5].

In the present study, we aimed to evaluate the effect of trauma severity on clinical and radiological results in the treatment of tibial plateau fractures.

Methods

A total of 59 patients who underwent surgical treatment due to tibial plateau fractures in our clinic were included in the study. All patients were given detailed information about treatment and a written informed consent was obtained from each participant. Ten patients were excluded from the study for reasons such as death, amputation and follow-up insufficiency. Forty-nine follow-up patients were evaluated retrospectively. According to the patients' preoperative radiographs, fracture classifications were performed according to AO [6] and Schatzker classification [7].

An intra-articular step or collapse of >3 mm, extra-articular translation of >1.0 cm or angulation of >10°, condylar extension >5 mm, varus/valgus instability of >10°, an open fracture, compartment syndrome requiring fasciotomy, or an associated ligament injury requiring repair with displaced tibial plateau were included to this study [8-10]. A pathologic fracture, a preexisting joint disease (osteoarthritis, inflammatory arthritis, or a prior fracture), a severe systemic illness (active cancer, chemotherapy, renal failure, hemophilia, or a medical contraindication for surgery), open growth plates, a vascular injury requiring repair (a Gustilo type III c fracture), a severe head injury (initial Glasgow coma scale score of <8) or other neurological condition that would interfere with rehabilitation were excluded from the study.

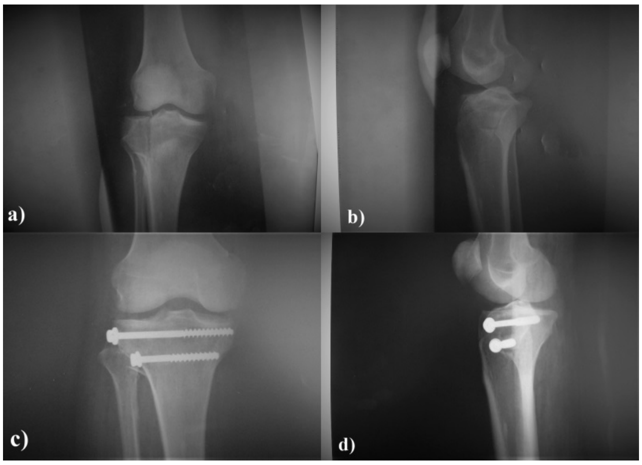

Figure 1: Tibial plateau Schatzker type I fractures treated with closed reduction and percutaneous screw fixation: Preoperative and postoperative appearance; a) anterior posterior, b) lateral radiography (respectively).

All the surgeries were performed by two surgeons in the study under spinal and general anesthesia. According to the condition of the soft tissue in the fracture area, fracture pattern and clinical condition of the patient, they were treated with ORIF, MIPPO or fixation with percutaneous cannulated screw after closed reduction (closed reduction and internal fixation; CRIF), and hybrid or circular external fixator (EF) **(Figures 1-3)**.

Autologous bone grafting from the iliac canal was performed to support the joint surface, which was collapsed on the surface. Open reduction and supportive plates or internal fixation with screws was performed to all patients undergoing bone grafting.

In all patients, first-generation cephalosporin was administered as a prophylactic antibiotic during half an hour before surgery and 48 h after it. During surgery, anatomic reduction was checked by using a C-arm fluoroscopy device. After surgery, isotonic and isometric quadriceps exercises were initiated. The earliest active movement of knee was initiated at postoperative 2^{nd} day. Patients were not allowed to bear weight on the knee joints for 8 to 12 weeks after surgery. Patients were called for monthly controls until the complete healing was achieved radiologically and clinically. The presence of healing of fracture radiologically and being able to walk without support with full body weight by relevant extremity and implementation of varus or valgus stress without pain were defined as the criteria of clinical healing. Satisfactory anatomic reduction was considered as a joint collapse of less than or equal to 4 mm and/or the presence of less than or equal to 5 mm of the plateau dilatation when compared to the width of the distal femoral condyles [9,10].

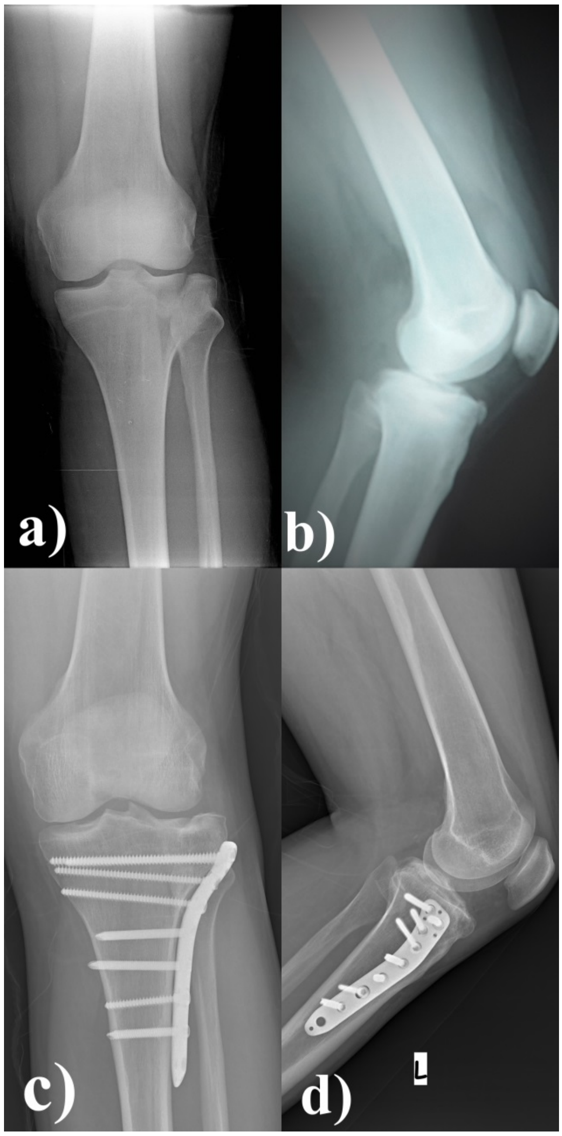

Figure 2: Tibial plateau Schatzker type II fractures treated with open reduction and locked plate fixation: Preoperative and postoperative appearance; a) anterior posterior, b) lateral radiography (respectively).

All patients were evaluated as fractures with low-energy (Schatzker type I-II-III) and high-energy (Schatzker type IV-V-VI) according to their age (under and over 40 years of age at injury) and fracture severity. Post-operative evaluation of all patients was performed clinically and radiologically according to Rasmussen criteria [11].

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) for Windows version 12.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in as median, minimum, and maximum values. The chi-square test was used for group comparisons of categorical variables, while the Mann-Whitney test was used to compare continuous variables between the groups. At 95% confidence interval (CI), a p value of <0.05 was considered statistically significant.

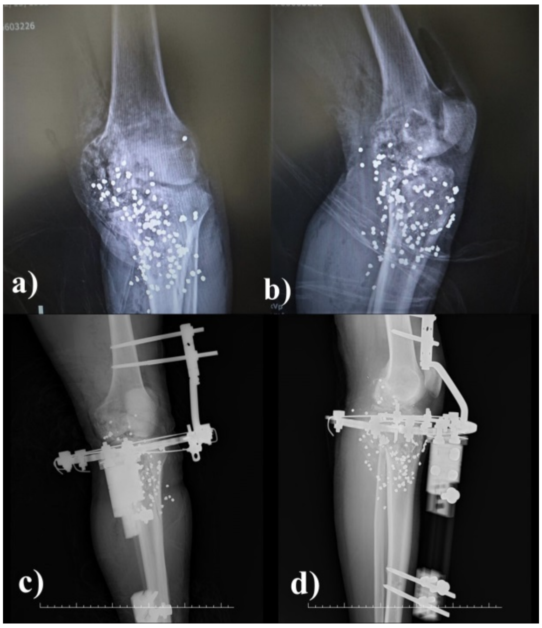

Figure 3: Tibial plateau Schatzker type VI fractures treated with closed reduction and external fixator: Preoperative and postoperative appearance; a) anterior posterior, b) lateral radiography (respectively).

Results

The demographic characteristics of 49 patients studied are shown in **Table 1**. The Schatzker type I and V fractures were the most frequent fracture types in the study population. According to AO classification, B1 and B3 fractures were the most frequent while C1 and C2 fractures were the second most frequent.

Low-energy fracture (Schatzker Type-I-II-III) was detected in 26 patients (53.1%) while high-energy fracture (Schatzker Type IV-V-VI) was observed in 23 patients (46.9%). Additional severe musculoskeletal injuries were present in 26.08% of patients with high-energy fractures and 38.46% of those with low-energy type. Five patients with high-energy injuries had ipsilateral peroneal nerve paralysis. One had a peroneal nerve avulsion and the other four had a nerve contusion. Tendon transfers were required for two patients with peroneal nerve injury. Fasciotomy was performed for two patients with closed fractures exposed to high-energy trauma due to acute compartment syndrome. Each of the four patients with high-energy injury had one of the ligament rupture as follow: the isolated rupture of outer lateral ligament, inner lateral ligament, anterior cruciate ligament, and combined inner and outer lateral ligament, separately. Of three patients with low-energy injury, two had internal ligament injury while one had anterior cruciate ligament injury.

Table 1: Patients demographics.

Variable		
Sex (Male)	n (%)	32 (65,3)
Affected extremity (Right)	n (%)	27 (55.1)
Mean age	years (range)	40,75 (29-68)
Follow-up time	month (range)	80 (14-240)
Timing of surgery	day (range)	4.30 (0-11)
Injury mechanism	n (%)	
Road traffic accident		28 (57.1)
Fall		8 (16.3)
Gun shot		5 (10.2)
Sports injury		4 (8.2)
Motorcycle accident		3 (6.1)
Industrial accident		1 (2.1)
Schatzker Type	n (%)	
Type I		13 (26.5)
Type II		7 (14.3)
Type III		6 (12.2)
Type IV		7 (14.3)
Type V		12 (24.5)
Type VI		4 (8.2)
AO classification	n (%)	
B1		11 (22.4)
B2		4 (8.2)
B3		11 (22.4)
C1		10 (20.4)
C2		9 (18.4)
C3		4 (8.2)
High- Energy injury	n (%)	26 (53.1)
Open fractures	n (%)	20 (40.9)
Surgery Type	n (%)	
ORIF (Open reduction and internal fixation)		18 (36)
CRIF (Closed reduction and internal fixation		16 (33)
EF (External fixation)		15 (31)

Eighteen (36%), 16 (33%), and 15 patients (31%) were treated with ORIF, CRIF and EF, respectively (**Table 2**). In six patients (12.2%), an autogenous bone graft was used to support the collapse of the joint surface. All patients undergoing bone grafting were applied open reduction and internal fixation with support plates and screws. Of these six patients, three were with Schatzker type II, two were with type III, and one was with a type IV fracture. Twenty-nine of the patients (59.1%) and 20 (40.9%) had close and open fractures, respectively. A total of 12.9%, 10% and 18% of open fractures were Gustilo type I, type II and type III a-b, respectively. After debridement of the open wounds in eight patients, external fixation was performed on the same day.

Table 2: The relation between severity of trauma and method of treatment.

Fractures type	ORIF (n=18)	CRIF (n=16)	EF (n=15)
Schatzker I	++++++	++++++	+
Schatzker II	++	+++	++
Schatzker III	+++	+	++
Schatzker IV	++++	+++	
Schatzker V	+++	+++	++++++
Schatzker VI			++++

At a mean of 14.4 weeks (range: 8 to 24 weeks) patients were allowed to load full weight on their extremities. In the last follow-up of our patients, the knee flexion was 113º (50º to 150º). In the last series of patients with low-energy trauma, the knee flexion arc was detected as 128.5º, while in the case with high-energy-trauma, the knee flexion movement was measured as 97.5º. There was a statistically significant difference between two groups in terms of knee joint movement (p<0.001). Thirty-four patients had full knee extension whereas 15 patients had extension loss of an average 6 degrees. The complete recovery was achieved without major complications in 43 of 49 patients (87.8%).

Major complications requiring secondary surgical procedure developed in three patients. Problem of non-union was detected in two patients with Gustilo type III-b open fracture treated by a circular external fixator. A deep infection developed in a patient with Schatzker type V tibial plateau fracture treated with plate osteosynthesis. Thrombophlebitis developed in two patients with circular EF and open reduction spongiosa screw fixation. In a case, which an external fixator was applied, a pin tract infection developed. In three patients, superficial soft tissue infection was observed after treatment.

According to the Rasmussen clinical evaluation score, 11 excellent, 25 good, 11 moderate and 2 poor results were detected. According to Rasmussen's radiological criteria, 17 excellent, 24 good, 8 moderate results were detected. 73.5% of the patients had clinically good and excellent results while 83.7% had radiographically good and excellent results.

According to different surgical methods, when Rasmusen clinical evaluation was performed; 83.3% of 18 patients with ORIF, 87.5% of 16 patients with CRIF and 46.7% of 15 patients treated with EF had good and excellent results. According to the radiological evaluation, 94.4% for ORIF, 87.5% for CRIF and 66.7% for EF had good and excellent results **(Figure 4)**.

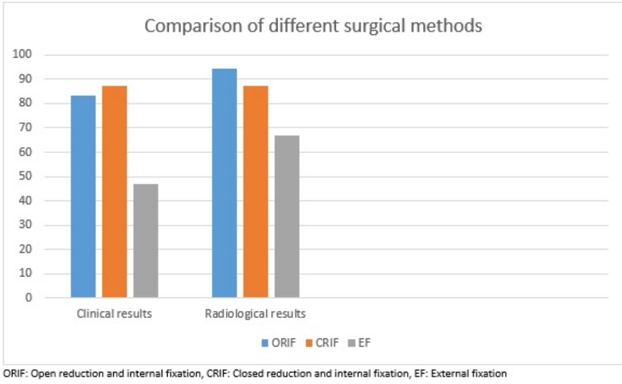

Figure 4: Comparison of different surgical methods.

When the Rasmussen clinical scores were evaluated according to the severity of the injury, 76.9% of the 26 patients with low-energy fracture had good and excellent results whereas 69.6% of 23 patients with high-energy fracture had good and excellent results. Despite the better scores in the low-energy group, no statistical significance was detected (p>0.05). According to the severity of injury parameter of Rasmussen radiological evaluation, good and excellent results were obtained in 92.3% of low-energy fractures while similar results were detected in 73.9% of high-energy fractures, indicating a statistically significant difference (p=0.011) **(Figure 5)**.

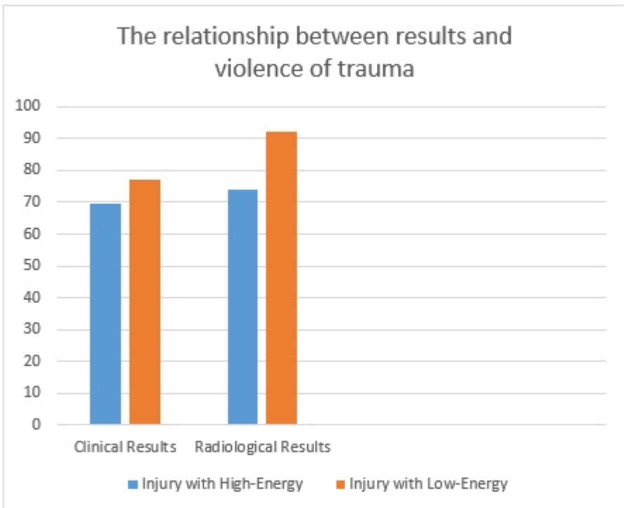

Figure 5: The relationship between results and violence of trauma.

In addition, there was a positive correlation between clinical and radiological improvement (r=0.64). However, there was a negative correlation between low/high-energy fracture and radiological improvement (r=-0.41). According to the effect of age on results, there was no statistically significant difference between clinical and radiological results between patients older and younger than 40 years old (p>0.05).

Discussion

Tibial plateau fractures involve a wide range of injuries, which occur on the joint surface at different degrees of collapse and separation, sometimes extend to the tibia accompanied by ligament injuries body [1-4]. Open reduction and internal fixation is the standard method in the surgical treatment of displaced tibial plateau fractures [12]. Tscherne and Lobenhoffer [13] reported that the primary goal in the treatment of tibial plateau fractures was reconstruction and stabilization of the joint surface, permitting early motion, and repair of other associated ligament injuries. Rasmussen et al. [11] showed that 44% of the 260 tibial plateau fractures were operated and 87% of them had acceptable, good and excellent clinical outcomes. Lansinger et al. [14] reported that 56% of 102 patients with tibial plateau fractures were operated and they had excellent and good results with a 90% totally during a 20-year follow-up period. During a mean follow-up of 80 months of 49 patients with tibial plateau fractures operated, 73.5% of the patients had clinically good and excellent results, while 83.7% of them had similar results radiographically in this study.

The rate of tibial plateau fracture with ligament injury is 10-30% [9,15]. Schatzker type II and IV fractures were observed more common with soft tissue lesions [10]. In our study, seven patients (14%) of tibial plateau fractures were observed with ligamentous injuries. However, its relationship with fracture severity was not detected. The incidence of neurological injury is low in pursuit of isolated tibial plateau fracture. In 320 series of cases study conducted by the Moore et al. [16], they reported that only three patients had peroneal nerve injuries. In this study, the peroneal nerve injury was detected in five patients (10%). All of these patients had type IV, V and VI fractures developed after a high-energy mechanism and were explored during the first operation. One case had a peroneal nerve avulsion, while the other four patients had a nerve contusion. Since any neurological improvement was not detected in two patients with peroneal nerve injury, the transfers of tendon were required.

Satisfactory clinical and functional results with low complication rates have been achieved in low-energy plateau fractures. However, unsatisfactory results have generally been reported in complex or bicondylar tibial plateau fractures [4,17,18]. In patients with high-energy tibial plateau fractures, various soft tissue problems such as abrasion, swelling, open wound, bulb formation and compartment syndrome are detected. Therefore, open reduction and internal fixation in the treatment of such high-energy fractures are frequently associated with complications such as wound healing problems, deep wound infections involving osteomyelitis and soft tissue necrosis [19]. Minimally invasive plaques, external fixation with limited internal fixation, or external fixation based on only ligamentotaxis principles have been used to avoid these problems, particularly in high-energy injuries [2,20]. Although the minimally invasive procedure is highly applicable in fractures with high-energy fragments, postoperative malalignment and symptomatic metallic hardware irritation have been reported frequently [20]. Singh et al. [2] treated tibial plateau fractures after high-energy injury (Schatzker's Grade VI) with a circular external fixator and reported that 85% of patients had excellent and good, whereas 20% and 5% of them had fair and poor results, respectively. They reported that 10% of the patients had pin tract infection, while 5% had non-union problems. In addition, they reported that the treatment of tibial plateau fractures after high-energy injury was frequently associated with complications. Koval et al. [21] reported that complications related to the nail in 5 (50%) of 10 patients treated with hybrid external fixator, while the problem of non-union was detected in one (10%) case. Stamer et al. [17] reported that there were good clinical and functional knee motion scores in 23 Schatzker type VI tibial plateau fractures treated with hybrid external fixation with or without limited internal fixation in 22 patients. They reported that nail path infection in one case, deep wound infections in three (13%) patients and nonunion in one case were detected.

Krupp et al. [22] showed that tibial plateau fractures treated with locked plate had better prognosis than those treated with locked plate and external fixator in terms of duration of union, malunion, knee stiffness and all other complications. However, the complication rate of complex fractures such as Schatzker type VI was 93% in those with locked plates whereas it was 83% in those with external fixator. In the study of comparing internal fixation with external one as treatment of bicondylar tibial plateau fractures, Chan et al. [23] reported that anatomic reduction was achieved in 92% of the patients with internal fixation, while it was achieved in 77% of those with external fixation. 26% of the patients treated with external fixator had pin-path infection, whereas no deep infection was observed in those treated with internal fixation. Rasmussen reported that there were no statistically significant differences between two groups in terms of clinical outcomes. In this study, three different surgical treatments were performed according to the clinical condition and fracture type of the patients. Good and excellent clinical results were obtained in 83.3% of 18 patients treated with ORIF, 87.5% of 16 patients treated with CRIF, 46.7% of 15 patients treated with EF. Good and excellent results were achieved in 94.4% of those with ORIF, 87.5% of those with CRIF and 66.7% of those with EF in terms of radiological evaluation. As 68.75% of the patients with external fixator had high-energy (type IV-V-VI) fractures according to the Schatzker classification, it can be determined that both the radiological and clinical outcomes are more negative than those of the other groups. In that study, major complications were detected in three of 49 patients, while minor complications were observed in five of them. It was determined that major complications were associated with high-energy fracture.

The effect of the fracture type on surgical outcomes is important. In the study comparing of arthroscopic assisted reduction internal fixation (ARIF) with ORIF for treatment of tibial plateau fractures Dall'Oca et al. [24] reported that there was no difference in Schatzker type I fractures, while ARIF was better in Schatzker type II-III-IV fractures, but without a significant difference. Moreover, although both medium and long term results were poor in both groups with Schatzker type V and VI fractures, they reported that fewer infections were observed in the ARIF group. Manidakis et al. [3] reported a mean union time of 8.6 weeks and 17 weeks in patients with Schatzker type II-III-IV fractures and those with Schatzker type IV-V-VI fractures, respectively. According to the American Knee Society score system, 76.7% of type I fractures, 78.5% of type II fractures, 57.1% of type III fractures, 66.6% of type IV fractures, 50% of type V fractures and 68.7% of type V fractures had good results. Complex fractures were associated with nonunion and malunion, but they noted that the nonunion ratio in low-energy fractures was low due to good blood support of the proximal tibial cancellous bone. In this study, 76.9% of patients with low-energy fracture had good and excellent results, while 69.6% of patients with high-energy fracture had good and excellent results. Although low-energy fractures had better clinical outcome than high-energy fractures, a statistically significant difference was not observed. 92.3% of the patients with low-energy fractures had good and excellent radiological results, while 73.9% of the patients with high-energy fractures had good and excellent results. Both radiological and clinical results were better in cases with high-energy fractures than those with low-energy type fractures. It was detected that the knee flexion angle in the final follow-up of cases with low-energy fractures was 128.5 degrees, while knee flexion movement arc was 97.5 degrees in those with high-energy fractures.

Our study has some limitations, including the small sample size, retrospective study and lack of a cost-effectiveness analysis.

Conclusion

In conclusion, based on our study results, we conclude that fracture type and severity of trauma are the main factors, which affect the functional and radiological results associated with the surgical treatment of tibial plateau fractures.

Competing Interests

The authors declare that they have no conflict of interest.

Authors' Contributions

All authors contributed toward data analysis, drafting and revising the paper and agree to be accountable for all aspects of the work.

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