SUBMITTED 20 JUL 20
REVISION REQ. 28 SEP 20; REVISION RECD. 28 OCT 20
ACCEPTED 9 DEC 20
ONLINE-FIRST: APRIL 2021
DOI: https://doi.org/10.18295/squmj.4.2021.059

The Mid-Term Radiological and Functional Outcomes of Bicondylar Tibial Plateau Fractures Managed with Open Reduction and Internal Fixation Using Dual Plates

***Angelo V. Vasiliadis,[1] Frideriki Poutoglidou,[1] Dimitrios Metaxiotis,[2] Anastasios Mpeletsiotis[2]**

2nd Departments of [1]Orthopaedic Surgery and [2]Orthopaedics, General Hospital of Thessaloniki "Papageorgiou", Thessaloniki, Greece
**Corresponding Author's e-mail: vasiliadis.av@gmail.com*

Abstract

Objective: This study was designed to evaluate the mid-term radiological and functional outcome of tibial plateau fractures treated by plating. ***Methods***: Patients with Schatzker type V and type VI tibial plateau fractures who were managed with open reduction and internal fixation using dual plates were included in this retrospective study. The functional evaluation of the patients was carried out with the visual analogue scale (VAS), the health-related quality of life status was measured using the Short Form-36 (SF-36) and the dimensions of pain, stiffness and function were assessed using the Western Ontario and McMaster Universities Arthritis Index (WOMAC). For the radiological outcome evaluation, the modified Rasmussen criteria were used. ***Results***: 57 patients (30 male and 27 female) were included in the study with a mean follow-up of 50.88 months. There were 23 Schatzker type V and 34 Schatzker type VI fractures. The majority of patients (86%) had a good to excellent radiological outcome. The mean VAS score was 1.65 for all the patients. The functional outcome was excellent in the majority of the patients. Among them, 5.3% (n = 3) suffered wound infection and all of the wounds healed after different treatments. All patients returned to their pre-injury activities of daily living and

employment status, while 53% of the patients returned to sporting activities.
Conclusion: Our findings support previous literature, which has demonstrated that bicondylar tibial plateau fractures can provide good to excellent radiological and functional outcomes if they were treated with open reduction and internal fixation with dual plating.
Keywords: tibial plateau fracture; bicondylar fracture; Schatzker classification; dual plating

Advances in Knowledge:

- The findings of the present study show that bicondylar tibial plateau fractures treated operatively with open reduction and internal fixation with dual plates had good to excellent mid-term radiological (modified Rasmussen criteria) and functional (SF-36 and WOMAC) outcomes at mid-term follow-up.
- In our study, there were no statistically differences between the early (≤ 48 hours) and delayed time to surgery with respect to superficial and deep wound infection.
- In accordance with the literature, open reduction and internal fixation with dual plates is a safe and effective treatment option for bicondylar tibial plateau fractures.

Application to Patient Care:

- Early surgical intervention of bicondylar tibial plateau fractures may be the key to successful treatment and improved functional outcomes.

Introduction

Tibial plateau fractures comprise approximately 2% of all fractures and tend to have a bimodal age distribution. Males, in the fourth decade of their life, are more likely to sustain this type of injuries due to high-energy trauma. Meanwhile, tibial plateau fractures are usually a result of low energy trauma in females, around the age of 70.[1] These injuries are often associated with soft tissue damage such as vasculature, nerves, ligaments and meniscus.[2] Schatzker proposed a classification system based on the two-dimensional radiological features, dividing tibial plateau fractures into six types, from type I to VI.[3] Luo et al.[4], in 2010, as a supplement to the Schatzker

Classification, introduced the three-column classification, based on the computed tomography scan images and the three-dimensional reconstruction, increasing the ability to identify the posteromedial fragment. These types of fractures, which pose a challenge even to a senior orthopaedic surgeon, still yield unsatisfactory results, even with the appropriate surgical treatment, due to their complexity and the associated soft tissue disruption.[2,3]

The objective of tibial plateau operative treatment is to obtain a stable osteosynthesis and to enable early mobilization of the knee joint. Various techniques have been proposed over the last few decades, each one with its own merits and demerits. Open reduction and internal fixation with various types of plates and screws remains the gold standard. Alternatively, circular external fixation with limited internal fixation (hybrid fixator) and arthroscopically assisted percutaneous reduction and internal fixation have been reported for the treatment of tibial plateau fractures.[5-7] Despite the plethora of the techniques, malalignment and secondary osteoarthritis are common complications encountered after surgery for complex tibial plateau fractures. The purpose of this study was to evaluate the mid-term radiological and functional outcome of tibial plateau fractures managed with open reduction and internal fixation (ORIF) using dual plates.

Methods

This study was examined and approved by our hospital's Institutional Review Board. Informed consent for medical photographs was obtained from the patients. All patients admitted with the diagnosis of bicondylar tibial plateau fractures over a period of 8 years, from January 2011 to December 2018, were included in our study. Only patients with Schatzker type V and VI managed with dual plating were included. The data were extracted from hospital records and outpatient department notes. The exclusion criteria were: 1) patients with bilateral fractures, 2) patients with ipsilateral femoral fractures (floating knee) or other lower limb fractures, 3) open tibial fractures and 4) severe head injury with neurological deficits.

The fractures were graded pre-operatively using Schatzker's classification system of tibial plateau fractures by routine anterior posterior and lateral radiographs of the knee. A computed tomography (CT) and a three-dimensional reconstruction was also

performed to evaluate the fractures' morphology and severity according to the three-column classification [Figure 1].[4] According to this classification, patients were categorized as: i) lateral and medial column; ii) lateral and posterior column; iii) medial and posterior column; and iv) lateral, medial and posterior column. A magnetic resonance imaging (MRI) was performed on each patient, in order to determine ligament and meniscal injuries. All the patients had their limb elevated and immobilized with an above knee cast. If edema was present and development of hemorrhagic fracture blisters occurred, surgery was delayed until soft tissue recovery, as evidenced by reduction of the swelling and appearance of skin lines and "wrinkle" sign.

All the patients underwent open reduction and internal fixation of the fracture through an anterolateral approach for fixation of the lateral column, an anteromedial approach for fixation of the medial column and a posteromedial approach for fixation of the posteromedial column. No temporary knee-spanning external fixation or bony skeletal traction was required preoperatively. The fractures were manipulated and fixed with plates under fluoroscopic guidance in order to assist and assess the reduction. Metaphyseal void was filled with allogenic bone grafts to support the reduction and to promote fracture healing in depressed and comminuted fractures patterns.

All the patients in the study called scheduled for a last follow-up evaluation. At the final follow-up radiographs of the knee were obtained in the anteroposterior and lateral views [Figure 2] to assess the articular depression, the condylar widening, the varus/valgus angulation and any evidence of post-traumatic degenerative changes. As far as functional outcome is concerned, the pain was assessed using the visual analogue scale (VAS), the health-related quality of life status was measured using the Short Form-36 (SF-36), the dimensions of pain, the stiffness and the function was assessed using the Western Ontario and McMaster Universities Arthritis Index (WOMAC). The radiological outcome was assessed using modified Rasmussen criteria for radiological assessment. Range of motion (ROM) was measured using a standard goniometer. Finally, all complications were documented during the last follow-up.

The statistical analysis was conducted with Jamovi software version 1.1.9. Continuous variables were given as mean, standard deviation and nominal variables were expressed as number of cases. The Shapiro-Wilk test was used to determine whether data were normally distributed. Continuous variables were analyzed using the independent samples t-test or the Mann–Whitney U-test. Categorical variables were analyzed using Pearson's Chi-square test or Fisher's exact test. A *p* value of less than 0.05 was considered to be statistically significant.

Results

Overall, 57 patients were included in the study. The demographic characteristics are presented in Table 1. All patients in the present study underwent surgery at a mean interval of 3.09 days (range 1 day to 9 days). The mean duration of hospitalization was 8.19 days ranging from 6 to 13 days. A follow-up ranging from 26 to 78 months (mean, 50.88 ± 16.56 months) showed that all fractures were healed [Table 1]. At the final follow-up, none of the patients reported knee instability while the mean ROM was 119.35° ± 4.84° (range, 110° to 125°) for type V and 110° ± 10.3° (range, 90° to 125°) for type VI [Table 2]. Treatment complications were rare, involving two cases of superficial wound infection (one male and one female patient with body mass index over 30 kg/m^2), which responded well to non-operative treatment, including local wound care and initial administration of intravenous antibiotics followed by oral antibiotics. One patient developed deep tissue infection that required surgical intervention with a full-thickness skin flap and intravenous antibiotics administration and resulted in complete resolution of the infection. The deep tissue infection was observed in a 86-years-old female with body mass index over 30 kg/m^2. Comparison of early (≤ 48 hours) and delayed time to surgery with respect to superficial and deep infection rate showed no statistical significant difference ($P = 0.565$). None of the patients developed compartment syndrome. Forty-nine patients (86%) had returned to their pre-injury occupation and activities of daily living, while eight (14%) patients reduced or modified their working status. Out of 57 patients, 19 reported a sport status before injury, while approximately 67% and 40% of them return to sport activity after surgical treatment for Schatzker type V and type VI, respectively [Table 1].

At the final follow-up, the mean VAS score was 1.39 (range, 0 to 2) for type V and 1.82 (range, 1 to 3) for type VI, the SF-36 was 90.65 ± 4.07 (range, 85 to 95) for type

V and 87.35 ± 4.31 (range, 80 to 95) for type VI and the WOMAC was 21.64 ± 7.14 (range, 10.9 to 29.8) and 25.26 ± 5.24 (range, 14.9 to 34.5). Radiological results were classified in four categories as per modified Rasmussen criteria. Of the 57 cases, 14 patients (24.6%) had excellent results, 35 patients (61.4%) had good, 7 patients (12.3%) had fair, while only one (1.7%) had poor results [Table 2]. Radiological outcomes according to the column specific plating are shown in Figure 3. Statistical analysis showed that there was a significant difference between the Schatzker type V and type VI in VAS and SF-36 ($p < 0.05$), while there was no significant difference on the WOMAC and modified Rasmussen criteria ($P = 0108$ and $P = 0.865$, respectively) [Table 2]. Finally, all the patients were evaluated at the follow-up for the range of motion, the extension lag, the flexion deficit and the malalignment [Figure 4].

Discussion

Tibial plateau fractures are among the most complex injuries and remain a challenge even for the most experienced orthopaedic trauma surgeons. In order to maintain a normal knee joint anatomy and function and accordingly, to ensure the maximal possible range of motion, the treatment should be focused on the restoration of joint stability, the alignment and the intra-articular congruity. [2] Open reduction and internal fixation is the gold standard for the management of bicondylar tibial plateau fractures,[8] despite the high rates of compartment syndrome, infection and wound necrosis being reported following placement of dual plating.[1,2,3]

The earlier reports of internal fixation with double plating by Thiruvengita Prasad et al.,[9] and Pun et al.,[10] had shown zero cases of deep tissue infection and only one case with superficial wound infection which healed after hardware removal.[9] Jagdev et al.,[3] reported a post-operative superficial infection in 8.69% of the patients treated with dual plates. Open reduction and internal fixation with doubles plates in Schatzker type V and type VI fractures had also shown high rates of infections ranging between 11% and 18%.[11-14] In our study, the overall infection rate was 5.3%, which is lower than the one reported in the current literature. It should be noted that the infections in our study were observed in only obese patients. Furthermore, the incidence of compartment syndrome reported in the literature in bicondylar tibial plateau fractures

treated with dual plating, ranges from 0% to 13%.[1,9,12,14] In the current study, no patient developed compartment syndrome.

Previous studies have demonstrated that the status of the soft tissue envelope at the time of injury and its dissection during surgery has a major impact on the final outcome.[3,15] Ellsworth et al.[16] have shown that early surgical fixation, within 48 hours, of lateral plateau fractures (Schatzker type I to III) can be performed safely and is not associated with a significant increase in the infection or the complication rates. We found no statistical significant difference in the overall complication and infection rate between fractures (Schatzker type V and VI) treated within 48 hours from the admission and those treated later. This suggests that even complex tibial plateau fractures can be treated immediately with an appropriate pre-operative treatment plan. In addition, surgical delay results in prolonged post-operative hospitalization and increased overall cost to the healthcare system.

Numerus surgical fixation methods have been proposed for the treatment of complex tibial plateau fractures such as a conventional dual-plate, a hybrid external fixator and/or less invasive stabilizing system.[7] Pun et al. reported a series of 21 bicondylar tibial plateau fractures treated with dual plating or with the Ilizarov fixator. The mean range of motion was 128.09° (range, 90° to 145°).[10] Jagdev et al. also reported a series of 26 patients with Schatzker type V and type VI using conventional dual plating. The mean range of motion was 123.4°, while five patients had a functional extension lag of less than 10°.[3] Christiano et al. demonstrated a mean ROM of 121° following open reduction and internal fixation of bicondylar tibial plateau fractures.[14] Our results (type V: 119.35°; type VI: 110°) seem to be quite similar with functional results reported by Christiano et al.[14] The possible explanations for the differences in the range of motion may be due to: i) the surgical technique, ii) the post-operatively initiation of physical therapy and iii) the exact time of the final follow-up.

In 2017, Mengi et al.[17] conducted a retrospective study in 38 patients with type C1 to C3 tibial plateau fractures treated with single (n = 23) or double plating (n = 15) and followed up for at least 12 months. Clinical outcomes were assessed by the Knee injury and Osteoarthritis Outcome Score and SF-36 and showed better scores when a single plate was applied relative to a double plate fixation. Pun et al.[10] evaluated

clinical and radiological outcomes of 21 patients with Schatzker type V and VI tibial plateau fractures treated with double plates and who were followed up for a mean period of 2 ½ years. In this study, the WOMAC questionnaire was used. The authors reported overall satisfactory results, without, however reporting differences between the two treatment groups. Our study also demonstrated favorable clinical outcomes (WOMAC and SF-36) following double plating in both groups, while scores in patients with Schatzker type V found to be statistically significant compared with patients with Schatzker type VI. Our results are similar to a retrospective study conducted in India. In this study, the Oxford Knee Score was greater in patients with Schatzker type V treated with dual plating.[3] Furthermore, Hasan et al.,[18] in a biomechanical comparative study suggested that thinner (3.5 mm) locking plates are likely viable alternatives to 4.5 mm locking plats and may be associated with less soft-tissue irritation and future wound healing complication.

Soft tissue damage in fractures around the knee joint, limb malalignment and delayed mobilization, are associated with joint instability and may be implicated in the pathogenesis of degenerative knee joint disease.[2] Parkkinen et al.,[19] reported that the articular congruity and restoration of the mechanical axis seem to have a role in prevention of post-traumatic osteoarthritis. Nevertheless, in a series of 73 patients, they confirmed that in the mid-term follow-up these factors do not appear to be detrimental to the functional outcomes. The age of the patient at the time of injury seem to be a significant prognostic indicator and correlated negatively with the functional outcomes.[3,9] In long-term follow-up studies, articular incongruities are well tolerated, while on the other hand, the stability of the knee joint is crucial for the final outcome.[2,19,20] In our study, using the Rasmussen criteria for radiological assessment, excellent to good outcome was achieved in the majority of the patients (86%), which is comparable to the similar series treated with dual plating.[11,21,22] According to the same rating system, Yao et al. reported a quite lower radiological result of 77% good to excellent after dual buttress plates fixation.[21] In a series of 34 patients with tibial plateau fracture type V and VI, Rohra et al. reported a result of 94% good to excellent satisfaction rate after plating with dual plates.[22] Consequently, we suggest that the dual buttress plating technique could achieve favorable fracture reduction and satisfactory clinical outcome.

Tibial plateau fractures are high-energy injuries, commonly associated with ligament, tendon or meniscus injuries, with an overall incidence reported between 12.3% and 35.2%.[2,9,10,23,24] The degree of widening of the tibial plateau has been proposed to be a possible predictor of concomitant soft tissue injury.[9,10] Stevens et al.[23] reported an incidence of ligament injuries in 24% of the cases of type I to III and 33% in type IV to VI tibial plateau fractures. Yu et al.,[24] reported an anterior cruciate ligament injury in 11.1% of the patients with type V and VI of tibial plateau fractures. They had also noticed a high incidence of meniscus injury (35.2%) in their study. In our study, 21.5% had soft tissue injuries including ligaments, tendons and meniscus. This marked variation in the incidence of soft tissue injuries reported in the literature may be due to the variety of the methods employed for the diagnosis of these injuries, such as MRI[9,24] or clinical examination.[2,10]

Conclusions

Despite the relatively small sample size, this study is aligned with the results of the current literature. Although technically demanding, open reduction and internal fixation of bicondylar tibial plateau fractures with dual plates is the most stable mechanical construct. The good to excellent mid-term radiological (modified Rasmussen criteria) and functional outcomes (SF-36 and WOMAC) support the fact that dual plating of bicondylar tibial plateau fracture is the optimal treatment option. The potential post-operative complications associated with open reduction, such as wound infection and compartment syndrome, can be prevented or/and minimized by general practices including timing of surgical intervention, meticulous soft tissue dissection and suture placement.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

No funding was received for this study.

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Table 1: Patients' characteristics of Schatzker Type V and VI tibial plateau fracture.

	Total (n = 57)	**Type V (n = 23)**	**Type VI (n = 34)**	***p***
Demographic				
Age (years), mean ± SD	52.44 ±16.21	51.35 ± 17.85	53.18 ± 15.22	0.680
Gender, male (%)	30 (53%)	6 (26%)	24 (71%)	< 0.001
Mechanism of injury (n, %)				0.356
RTA	30 (52.6%)	12 (52%)	18 (53%)	
Fall	23 (40.4%)	11 (48%)	12 (35%)	
Sport	2 (3.5%)		2 (6%)	

Other	2 (3.5%)		2 (6%)	
Time to surgery (days), mean ± SD	3.09 ± 2.2	2.96 ± 2.16	3.18 ± 2.25	0.726
Early (≤ 48 hours)	30	13	17	0.629
Delayed (> 48 hours)	27	10	17	
Hospitalization (days), mean ± SD	8.19 ± 2.16	8.04 ± 1.99	8.29 ± 2.29	0.778
Follow-up (months), mean ± SD	50.88 ± 16.56	49.75 ± 15.03	51.65 ± 17.69	0.673
Related fractures (n, %)				0.193
No fractures	39 (68.5%)	17 (74%)	22 (54%)	
Fibula	12 (21%)	4 (17%)	8 (24%)	
Radius	2 (3.5%)		2 (6%)	
Clavicle	2 (3.5%)		2 (6%)	
Rib	2 (3.5%)	2 (9%)		
Ligament injuries (n, %)				< 0.05
No injuries	49 (86%)	23 (100%)	26 (76%)	
ACL	6 (11%)		6 (18%)	
PT	2 (3%)		2 (6%)	
Meniscal injuries (n, %)	6 (11%)	2 (9%)	4 (12%)	
Return to work/ADL (n, %)				0.549
Yes	49 (86%)	19 (83%)	30 (88%)	
Part-time	8 (14%)	4 (17%)	4 (12%)	
Return to sports (n, %)				0.228
Yes	2 (11%)	2 (22%)		
No	9 (47%)	3 (33%)	6 (60%)	
Part-time	8 (42%)	4 (45%)	4 (40%)	

RTA : road traffic accidents, ACL : anterior cruciate ligament, PT : patella tendon, ADL : activities of daily living.

Table 2: Functional and radiological outcomes of tibial plateau fractures.

	Total (n = 57)	**Schatzker Classification**		***p***
		Type V (n = 23)	**Type VI (n = 34)**	
VAS	1.65 ± 0.67	1.39 ± 0.66	1.82 ± 0.63	< 0.05
SF-36	88.68 ± 4.48	90.65 ± 4.07	87.35 ± 4.31	< 0.05

WOMAC	23.80 ± 6.28	21.64 ± 7.14	25.26 ± 5.24	0.108
Rasmussen[#]				0.865
Excellent	14	6	8	
Good	35	14	21	
Fair	7	3	4	
Poor	1		1	
Total	57	23	34	
ROM (°)	113.77 ± 9.65	119.35 ± 4.84	110 ± 10.3	< 0.001

[#] *Rasmussen assessment criteria for radiological outcome; L-MC : lateral-medial column; L-PC : lateral-posterior column; L-M-PC : lateral-medial-posterior column; VAS : visual analogue scale; SF-36 : Short-Form 36 Health Survey; WOMAC : Western Ontario and McMaster Universities Arthritis Index; ROM : range of motion*

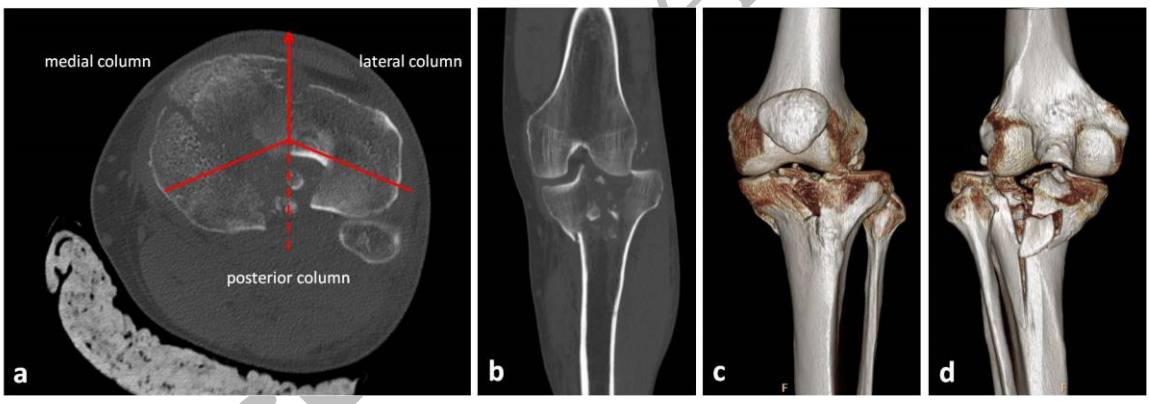

Figure 1: Pre-operative, all the fractures were classified with the three-column classification system using two-dimensional (a, b) and three-dimensional computed tomography images (c, d).

Figure 2: Plain radiograph (a) of left tibia showing the bicondylar tibial fracture and metaphyseal involvement (Schatzker Type VI). Plain radiographs (b, c) taken at the final follow-up showing the anatomic reduction.

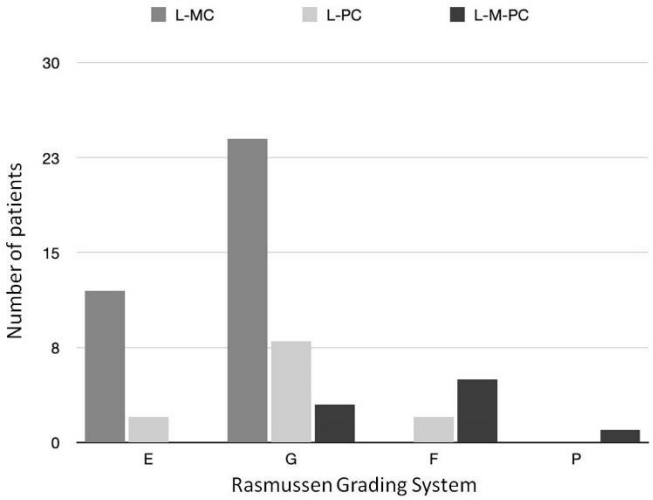

Figure 3: Radiological outcomes of tibial plateau fractures according to the column specific plating.

Figure 4: Functional pictures showed good flexion without extension lag (a, b), no varus/valgus malalignment (c) and patient able to do cross leg sitting (d).