Eur J Orthop Surg Traumatol (2018) 28:85–93
https://doi.org/10.1007/s00590-017-2017-6

ORIGINAL ARTICLE • KNEE - FRACTURES

# The impact of acute compartment syndrome on the outcome of tibia plateau fracture

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Received: 3 May 2017 / Accepted: 15 July 2017 / Published online: 7 August 2017


**Abstract**
*Background* Acute compartment syndrome (ACS) is often associated with tibial plateau fractures and is a limb-threatening injury. Staged management through fasciotomy with delayed definitive fixation can prevent muscle necrosis and increase limb salvage rates. This procedure opens a large area for potential contamination and infection in the lower extremity. Recent studies have shown an increased risk of infection following fasciotomy and staged management for tibial plateau fractures. This study reports the rate of infection, delayed union, and nonunion in patients with this injury pattern.
*Methods* This study was a retrospective chart review, which received institutional review board approval. It surveyed patient radiographs, clinical notes, and operating room reports from a level I trauma center between 2010 through 2016.
*Results* The results demonstrated that 23 out of 221 consecutive patients with ACS of the lower extremity presented with tibial plateau fracture over a 65-month period. Of these 23 patients, four were lost to follow-up or died. Nineteen patient charts were surveyed, 63% were male (12/19) and 37% were female (7/19). One patient developed deep infection (5.3%). Three patients experienced delayed union (15.8%), and their fractures eventually achieved union without intervention. The mean time to union was 14 weeks. Schatzker type V/VI fractures were the most prevalent type of fractures seen among patients.
*Conclusion* The infection rate found is lower than in other recently published studies. The incidence of delayed union or nonunion of the fracture was also lower than in other publications in the literature. Early decompression through double- or single-incision fasciotomy does not increase the risk of infection or nonunion of the fracture. The delayed union rates found in this study are lower than those in previous studies.
*Level of evidence* Level IV prognostic.

**Keywords** Tibial plateau fracture · Acute compartment syndrome · Infection · Nonunion

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## Background

Compartment syndrome is a limb-threatening emergency, and its association with high-energy bicondylar tibial plateau fractures is well documented in the literature [1–3]. The complexity of tibial plateau fractures makes treatment decisions very challenging. Prior to staged management with spanning external fixator followed by definitive fixation, infection rates for tibial plateau fractures were documented as high as 80% [1, 4]. This may have been due to multiple factors including the damaged soft tissues, the large extensile exposures used, and lengthy surgery times. The improved implant technology, smaller incisions, and staged management have greatly improved complication rates in this injury pattern compared with previous operative and non-operative management techniques [5, 6]. Additionally, while the timing of fixation with relation to the closing of fasciotomy wounds has not been shown to influence infection rate, it is still important for the surgeon to allow adequate healing of the soft tissue envelope prior to definitive fixation [7–9]. While compartment release is necessary to salvage the limb and prevent muscle necrosis, it opens up a large area of the lower extremity for possible contamination while in the hospital setting and subsequent increased risk of infection. Has the adoption of staged management for high-energy proximal tibia fractures, wound vacuum-assisted closure (VAC) and improved surgical techniques and implants technology, improved the outcome (based on decreased infection and nonunion rates) of tibial plateau fractures requiring fasciotomy release for acute compartment syndrome (ACS)? These questions are decidedly unanswered in the literature, with contradictory conclusions regarding the association of acute compartment syndrome with risk of infection and/or nonunion.

The study hypothesized that patients with combined tibial plateau fracture and compartment syndrome may do as well as those without acute compartment syndrome. The purpose of this study was to report the rate of complications (specifically infection and nonunion rates) in patients with combined acute compartment syndrome and tibial plateau fracture.

## Methods

This study was a retrospective chart review approved by the institutional review board (IRB). The study included a review of the academic medical center's level I trauma registry covering a 65-month time period between 2010 and 2016 in which cases of acute compartment syndrome (ACS) of the lower extremity were assessed for concurrent tibial plateau fracture. ACS was defined as having occurred if a fasciotomy (using either one or two incisions) was performed. The study included only patients with post-traumatic ACS. The patient lists were generated using the International Classification of Disease (ICD), 9th revision code for traumatic compartment syndrome of the lower extremity (958.92), as well as from the operating room case report records of fasciotomies performed. Patients who developed postoperative ACS and patients that did not receive a fasciotomy were excluded.

The study included patients aged between 18 and 79 years whose medical records and radiographs were reviewed. Medical records were reviewed for patients' demographics, injury, and surgical variables, such as age, gender, height, weight, affected extremity, mechanism of injury, fracture classification, pertinent medical history, other injuries incurred, vascular injury or associated dislocations, Gustilo–Anderson type, provisional soft tissue coverage, definitive soft tissue coverage, surgical approaches, implant used, time to fasciotomy, time to definitive soft tissue coverage, time to definitive fixation, total hospital days, time to union, total follow-up time, and infection status. Three criteria were needed to be present to classify as deep infection: clinical signs and symptoms, positive bacterial culture of the wound, and osteosynthesis material visible or palpable in the wound [10]. Clinical signs and symptoms of wound infection included redness, swelling, wound dehiscence, and drainage. However, the drainage was the main clinical sign of deep infection. The radiographs were reviewed for Schatzker classification, *Arbeitsgemeinschaft für Osteosynthesefragen*/Orthopaedic Trauma Association (AO/OTA) classification, and evidence of union. The radiographs were reviewed for union. Bridging of the fracture by callus, bone, or trabeculae; bridging of the fracture at three cortices; and obliteration of the fracture line and/or cortical continuity were the criteria used to determine radiographic union [11]. Nonunion was defined as lack of callous formation at 36 weeks from presentation of injury or lack of progressive healing during follow-up, while delayed union was defined as lack of callous formation by 20 weeks. Mechanism of injury was classified as high energy or low energy based on the description of the traumatic event. Motor vehicle collisions, falls greater than 10 feet, or high-speed incidents resulting in trauma were considered high-energy events. Low-energy events included falls less than 10 feet and slow-speed incidents resulting in trauma. The surgical management and case management of the injury were left at the discretion of the individual attending surgeons. There were nine attending surgeons involved in the definitive fixation of the tibia plateau fractures. Range of methods included two stages protocol with fasciotomy and spanning external fixator followed by definitive ORIF after wound closure or external fixation for definitive fixation if the wound was not appropriate for ORIF.

### Surgical technique

All patients received a standard four-compartment fasciotomy and spanning external fixators for initial fracture stabilization. A single-incision fasciotomy, as described by Matsen, was performed in one case; all others utilized the two-incision technique, as described by Mubarak [12, 13]. The fasciotomy wound was managed with vacuum-assisted closure (VAC) application. The patient received second-look debridement and irrigation after 48 h. We checked the ability to close the skin at that time and then one week later, we checked the ability to close the skin. The patient received secondary wound closure via split-thickness skin grafting (STSG) if the wound was not closed by this time. Time to closure and fixation was determined by patient healing and recovery status. This was made at the discretion of the attending surgeon. Definitive open reduction and internal fixation (ORIF) or circular external fixator application was performed when the soft tissue conditions permitted (2–4 weeks). The surgery for the tibial plateau fracture was performed in standard fashion. This means two approaches: anterolateral and posteromedial. The goals of surgery were anatomical reduction and rigid internal fixation to restore the articular surface congruity to allow early range of motion. We extended the medial fasciotomy incision for the posteromedial approach. A separate incision for the anterolateral approach was made away from the fasciotomy wound. Provisional fixation was accomplished using Kirschner wires, and appropriate reduction was verified using fluoroscopy. Severe bicondylar fractures began with fixation of the medial condyle and subsequent fixation of the lateral condyle. Definitive fixation was achieved with plate fixation, and appropriate definitive reduction is verified via fluoroscopy [6, 14]. Implant choice was based on the surgeon's preference.

### Statistical analysis

Statistical calculations were performed by an independent statistician using Excel® software (Microsoft Corporation; Redmond, WA). Descriptive statistics such as the mean, standard deviation, and frequency were used; no inferential statistics were computed.

## Results

A total of 221 patient encounters coded for traumatic compartment syndrome of the lower extremity were generated from this chart review, which spanned the 65-month study period (Fig. 1). From these encounters, 23 patients (10.4%) presented consecutively with tibial plateau fracture and acute compartment syndrome. Four of these patients were either lost to follow-up or died of their injuries, and the variables of the remaining 19 patients (7 females and 12 males) were analyzed. All patients healed and had eventual union of their fracture. Only one patient developed infection of the tibial plateau, an incidence of 5.3%. The majority of fractures seen in this study were due to a high-energy mechanism of injury (75%), and the Schatzker type V/VI fracture was the most frequent (83.3%) type of fracture seen (Tables 1, 2). The mean time to fasciotomy was 12 h and 32 min (range 1 h

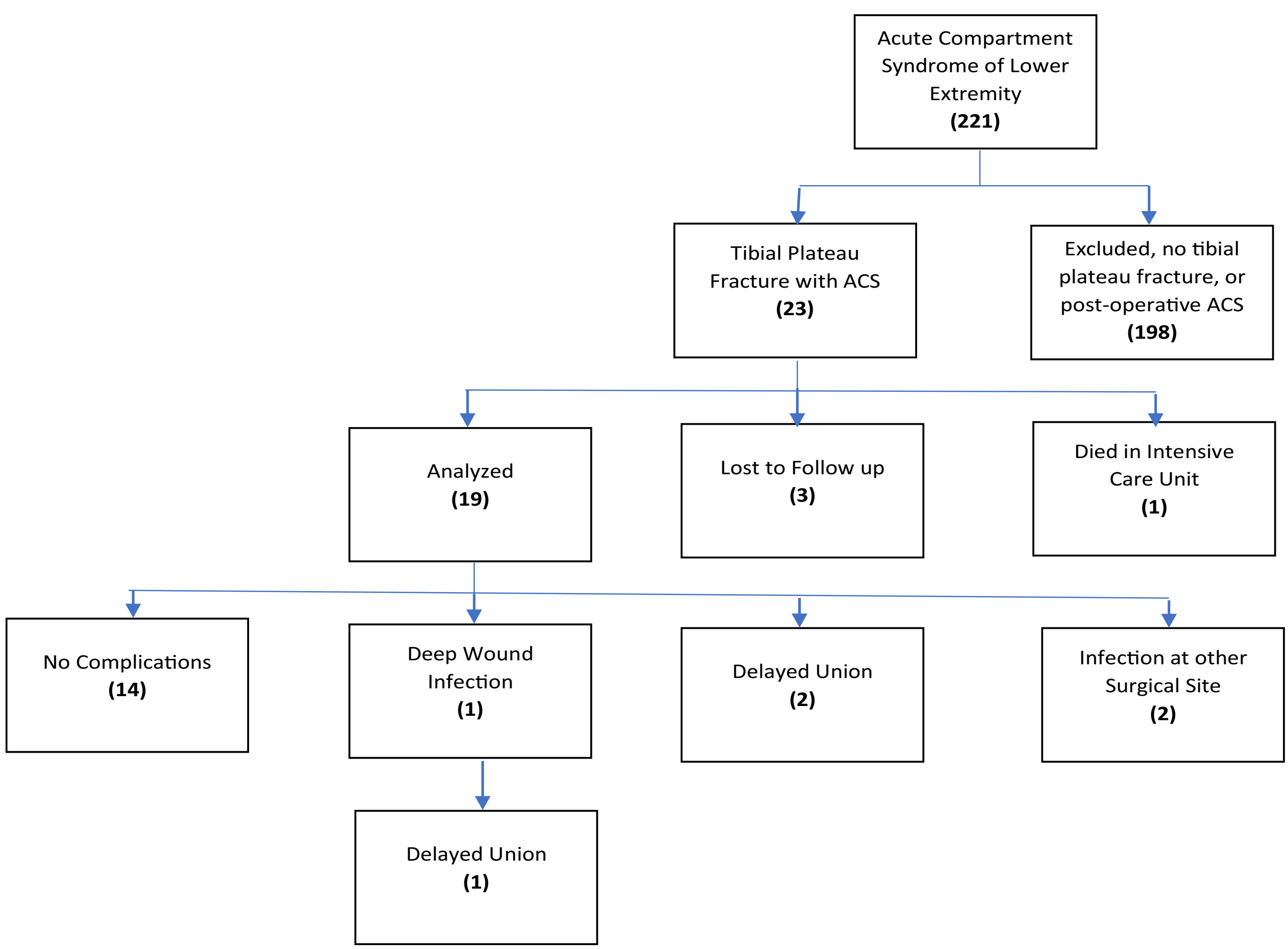


**Fig. 1** Flowchart of patient outcomes

**Table 1** Patient variables

| Case no. | Age (year)/ gender/BMI | Affected extremity/ mechanism of injury | Diabetes/ hypertension/ smoking |
|---|---|---|---|
| 1 | 33 M/40.2 | Right/high | N/Y/Y |
| 2 | 42 F | Right/high | Unknown |
| 3 | 58 M/31.1 | Right/high | N/N/Y |
| 4 | 70 M/34.0 | Right/high | N/Y/N |
| 5 | 66 F/25.9 | Left/low | N/N/Y |
| 6 | 50 M/27.6 | Right/high | N/N/Y |
| 7 | 28 F/28.0 | Left/high | N/N/N |
| 8 | 30 F/33.2 | Left/high | N/N/N |
| 9 | 72 F | Right/low | Y/Y/N |
| 10 | 38 M/27.5 | Left/high | Y/Y/N |
| 11 | 53 M/32.0 | Right/low | Y/Y/N |
| 12 | 50 M/32.6 | Right/low | Y/Y/Y |
| 13 | 29 M/41.5 | Right/high | N/Y/N |
| 14 | 54 M/37.4 | Left/high | Y/Y/Y |
| 15 | 59 F/39.8 | Left/low | N/N/N |
| 16 | 58 F/39.1 | Right/low | N/N/N |
| 17 | 29 F/35.2 | Right/high | N/N/N |
| 18 | 29 F/26.3 | Right/high | N/N/N |
| 19 | 28 M | Left/high | N/N/Y |
| 20 | 31 M | Right/high | Unknown |
| 21 | 22 M/28.0 | Right/high | N/N/N |
| 22 | 25 M/22.8 | Left/high | N/Y/N |
| 23 | 47 M | Left/high | Unknown |

49 min–34 h 20 min) following presentation at triage in the emergency department (Table 3). Four patients had diabetes, eight had hypertension, and seven were smokers or former smokers. All four patients who had diabetes also had hypertension. Two former smokers had diabetes and hypertension. One patient had a normal body mass index (BMI), six had a BMI greater than 25 (overweight), and eleven had a body mass index (BMI) greater than 30 (obese). The average number of hospitalization days was 12.2 (range 6–23 days).

The patient that developed an infection initially received a STSG and negative-pressure wound therapy (NPWT) for coverage of their soft tissue and was discharged from the hospital prior to definitive fixation. The fracture became infected (based on previously specified deep infection criteria) with methicillin-resistant *Staphylococcus aureus* (MRSA), and the patient returned to the hospital 22 days after placement of the graft. Excision plus debridement was performed, followed by application of a new NPWT dressing. Two days later, a second STSG was placed, and definitive fixation using a Taylor Spatial Frame (TSF)™ (Smith & Nephew plc; London, UK) occurred three days later. The patient had no further complications, and union was achieved, although it was delayed.

Two patients (10.5%) developed infections at sites other than the tibial plateau. One poly-trauma patient developed deep infection and nonunion of the distal femur fracture ipsilateral to the plateau fracture. A second poly-trauma patient developed infection of the contralateral pilon fracture. Nonunion occurred in one patient (5.3%), and delayed healing was observed in two patients, including the patient with infection of the tibial plateau (10.5%). The patient with nonunion did not achieve union within 36 weeks, but achieved union without surgical revision or other intervention at 48 weeks (336 days). The patient with delayed healing and infection achieved union at 22 weeks (157 days). This patient did not require additional intervention besides the care described for the infection. The second patient with delayed healing achieved union at 24 weeks (172 days). This patient had a previous orthopedic injury with intramedullary rod placement in the femur of the ipsilateral lower extremity (Figs. 2, 3). The patient follow-up period spanned from a minimum of 12 weeks (86 days) to a maximum of 24 months (734 days). None of the patients had any complications up to their discharge dates following definitive fixation.

Of the four patients lost to follow-up, one died in the intensive care unit due to acute respiratory distress syndrome on hospital day 3; this individual received index surgery with fasciotomy 22 h after presentation at the hospital. Three other patients were lost to follow-up, one of whom left before definitive fixation could be performed at the hospital; this individual was injured while traveling and left the hospital to return home against the doctor's advice for follow-up care. This patient received the initial temporary knee-spanning external fixation and provisional soft tissue coverage at the hospital, but left prior to definitive fixation. The other two patients had all initial surgeries performed at the hospital, but did not return for follow-up at the Orthopedics Clinic.

## Discussion

The current study found that tibial plateau fractures with post-traumatic compartment syndrome resulting in infection do not occur as frequently in our population as has been previously reported. Only one case of infection was found among 19 patients. An additional two patients had infections at other surgical sites.

The patient in this study who developed infection of their tibial plateau site had other risk factors besides having received a fasciotomy. This individual had diabetes, had hypertension, and was obese, all known modifiable risk factors for infection [6]. They were also one of only two patients that received STSG for definitive soft tissue coverage of their wounds. The other patient requiring skin graft received that for coverage of the lateral incision, and

**Table 2** Injury and surgical variables

| Case no. | Schatzker/AO-OTA 41/status/Gustilo–Anderson type | Fasciotomy/provisional soft tissue coverage/vessel loop closure/definitive soft tissue coverage | Definitive fixation/surgical approach/implants |
|---|---|---|---|
| 1 | II/B3/closed | Single/NPWT/no/DPC | ORIF/isolated lateral/single plate |
| 2 | VI/C2/closed | Single/NPWT/yes/DPC | ORIF/isolated lateral/single plate |
| 3 | VI/C3/closed | Dual/NPWT/no/DPC | ORIF/isolated lateral/single plate |
| 4 | VI/C3/closed | Dual/NPWT/no/DPC | CIRCULAR/n/a/circular ExFix |
| 5 | VI/C2/closed | Dual/NPWT/no/DPC | ORIF/isolated medial/single plate |
| 6 | VI/C3/closed | Dual/NPWT/no/DPC | ORIF/medial and lateral/single plate |
| 7 | V/C3/closed | Dual/NPWT/no/DPC | ORIF/isolated medial/single plate |
| 8 | II/B3/closed | Dual/NPWT/no/DPC | ORIF/isolated lateral/single plate |
| 9 | VI/C3/closed | Dual/NPWT/no/DPC | ORIF/isolated lateral/single plate |
| 10 | VI/C1/closed | Dual/NPWT/yes/DPC | ORIF/isolated lateral/single plate |
| 11 | VI/C3/closed | Dual/WTD, NPWT/no/STSG | CIRCULAR/n/a/circular ExFix |
| 12 | VI/C2/closed | Dual/NPWT/yes/DPC | ORIF/medial and lateral/two plates |
| 13 | VI/C3/closed | Dual/NPWT/no/DPC | ORIF/medial and lateral/two plates |
| 14 | V/C3/closed | Dual/NPWT/no/DPC | ORIF/medial and lateral/two plates |
| 15 | VI/C3/closed | Dual/WTD, NPWT/yes/DPC | ORIF/isolated lateral/single plate |
| 16 | VI/C3/closed | Dual/NPWT/yes/DPC | ORIF/medial and lateral/two plates |
| 17 | VI/C3/closed | Dual/NPWT/no/DPC | ORIF/medial and lateral/two plates |
| 18 | VI/C3/open/2 | Dual/NPWT/no/DPC | ORIF/medial and lateral/two plates |
| 19 | VI/C3/closed | Dual/NPWT/yes/DPC | ORIF/isolated lateral/single plate |
| 20 | VI/C3/closed | Dual/STSG, DPC | Unknown |
| 21 | I/C3/open/3a | Dual/NPWT/yes/DPC | ORIF, EXFIX (to protect extensor mechanism repair) |
| 22 | VI/C3/closed | Dual/NPWT/no/DPC | ORIF/medial and lateral/two plates |
| 23 | V/C1/closed | Dual/NPWT/no | Not performed |

*WTD* wet-to-dry dressing, *NPWT* negative-pressure wound therapy, *DPC* delayed primary closure, *STSG* split-thickness skin graft, *ORIF* open reduction, internal fixation, *ExFix* external fixation

delayed primary closure for the medial incision. Unfortunately, that individual was lost to follow-up. All of the other patients received delayed primary closure for the definitive coverage of their wounds. The extensive soft tissue damage requiring STSG may have contributed to the increased risk of infection in this patient, as well as the graft's reliance on a well-nourished tissue bed for nutrition [5]. Any potential failures in this graft after the patient's discharge from the hospital, as well as their comorbidities, could be a contributing factor in the development of this patient's deep infection of the fracture site. Because of the variability in the soft tissue injury patterns, we were unable to determine whether dressing choice impacted infection rate. In addition, this patient was discharged from the hospital prior to definitive fixation. A total of six patients were discharged prior to fixation (31.6%); none of the other five had complications. All six individuals were released from the hospital following definitive soft tissue coverage and prior to definitive fixation.

Wound VACs are used as a standard of care by our facility in patients who received a fasciotomy. Wound VAC employs a negative-pressure wound therapy (NPWT) technique that has surfaced as a modality for coverage of open wounds before delayed closure. A study by Blum showed a significantly lower deep infection rate in fractures treated with NPWT (8.4%, 14/166) compared to fractures treated with conventional dressing (20.6%, 13/63, $P = 0.011$) [15]. A study by Yang focused on the time to definitive closure in patients receiving a fasciotomy and compared vacuum-assisted closure (VAC) with patients who did not receive VAC post-fasciotomy. The study found that patients receiving VAC therapy had a mean time to definitive closure of 6.7 days (68 wounds, 34 patients), whereas the time to definitive closure in the control group was 16.1 days (70 wounds, 34 patients). This was considered statistically significant ($P < 0.05$) [16].

NPWT has the advantage of converting an open environment created by the fasciotomy incisions to a closed environment. In theory, this closed environment adds additional protection to the wound from the outside environment between operational procedures, thereby decreasing the risk of secondary nosocomial infections. NPWT also decreases the need for frequent dressing changes, another potential source for contamination and subsequent infection [17]. Given this information and prior studies, we believe

**Table 3** Time course and outcomes

| Case no. | Time to fasciotomy (hours:min) | Time to definitive soft tissue coverage (days) | Time to definitive fixation (days) | Total hospital days | Time to union (weeks) | Total follow-up time (weeks) | Infection status | Union status | Other complications |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 16:19 | 19 | 19 | 11 | 8 | 24 | No | Union | None |
| 2 | 11:45 | 2 | 6 | 9 | Unknown | 0 | Unknown | Unknown | Unknown |
| 3 | 9:46 | 3 | 11 | 13 | 12 | 14 | No | Union | None |
| 4 | 1:49 | 5 | 5 | 12 | 12 | 12 | No | Union | None |
| 5 | 5:27 | 4 | 4 | 6 | 14 | 104 | No | Union | None |
| 6 | 8:52 | 7 | 7 | 13 | 13 | 13 | No | Union | None |
| 7 | 33:26 | 5 | 12 | 15 | 12 | 13 | No | Union | None |
| 8 | 28:22 | 3 | 19 | 9 | 10 | 12 | No | Union | None |
| 9 | 9:58 | 2 | 11 | 18 | Unknown | 3 | Unknown | Unknown | Unknown |
| 10 | 8:52 | 6 | 9 | 10 | 48 | 53 | No | Union | Delayed union |
| 11 | 6:46 | 25 | 28 | 11 | 22 | 26 | Y, deep | Union | Delayed union |
| 12 | 24:53 | 21 | 21 | 6 | 24 | 9 | No | Union | Delayed union |
| 13 | 7:10 | 12 | 12 | 16 | 12 | 12 | No | Union | None |
| 14 | 22:53 | 5 | 12 | 23 | 12 | 13 | No | Union | SSI of R Pilon Fx |
| 15 | 14:008 | 5 | 32 | 8 | 17 | 27 | No | Union | None |
| 16 | 5:24 | 7 | 21 | 11 | 11 | 22 | No | Union | None |
| 17 | 24:34 | 7 | 10 | 13 | 11 | 55 | No | Union | None |
| 18 | 10:59 | 8 | 13 | 20 | 9 | 73 | No | Union | None |
| 19 | 34:20 | 2 | 10 | 11 | 12 | 13 | No | Union | None |
| 20 | 25:38 | Unknown | Unknown | 8 | Unknown | 0 | Unknown | Unknown | Unknown |
| 21 | 3:30 | 4 | 4 | 10 | Unknown | 104 | No | Unknown | Deep infection and nonunion of open R distal femur Fx |
| 22 | 6:48 | 6 | 10 | 14 | 12 | 29 | No | Union | None |
| 23 | 22:36 | n/a | n/a | 3 | n/a | 0 | n/a | n/a | ARDS/DOW |

*SSI* surgical site infection, *Fx* fracture, *ARDS* acute respiratory distress syndrome, *DOW* died of wounds

that the addition of NPWT reduced the infection risk for patients in our study.

There is considerable variance in the reported rates of infection and complications stemming from tibial plateau fractures presenting with acute compartment syndrome. Blair and colleagues recently reported a greater incidence of nonunion and infection when ACS was present than in those without [18]. Their infection rate was 22% (5/23) in the cohort with fasciotomy performed versus 1.4% (1/69) when no fasciotomy occurred [18]. Shah and Karunakar examined dual plating of high-energy tibial plateau fractures and found a 20% infection rate in closed fractures requiring fasciotomy [19]. However, this occurred in one patient out of five, a very small sample size. Their overall infection rate in the study was 13.8% (4/29), and they concluded that there was a lower risk of deep infection than previous reports. Momaya and colleagues studied risk factors for infection after operative fixation of tibial plateau fractures by first identifying patients that developed deep infection and then comparing variables [20]. There was an 11.1% total deep infection rate and an 8.3% total compartment syndrome rate. Among those with deep infection, there was a 22% compartment syndrome rate (13/59) versus a 6.6% rate of compartment syndrome in patients without infection; the conclusion was that compartment syndrome was an independent risk factor for infection. Parkkinen and colleagues also studied risk factors for deep infection following plate fixation of proximal tibial fractures and identified 34 patients with deep infection [10]. Of those, 38% had compartment syndrome (13/34) versus 9% in the control group (12/136). Zura and colleagues, when examining the influence of timing of definitive fixation on outcome, found an overall deep infection rate of 11% (9/81) [7]. Morris and colleagues found a modifiable patient risk factor for smoking associated with deep infection and had a high rate of deep infection of AO/OTA 41-C fractures in spite of staged management [21].

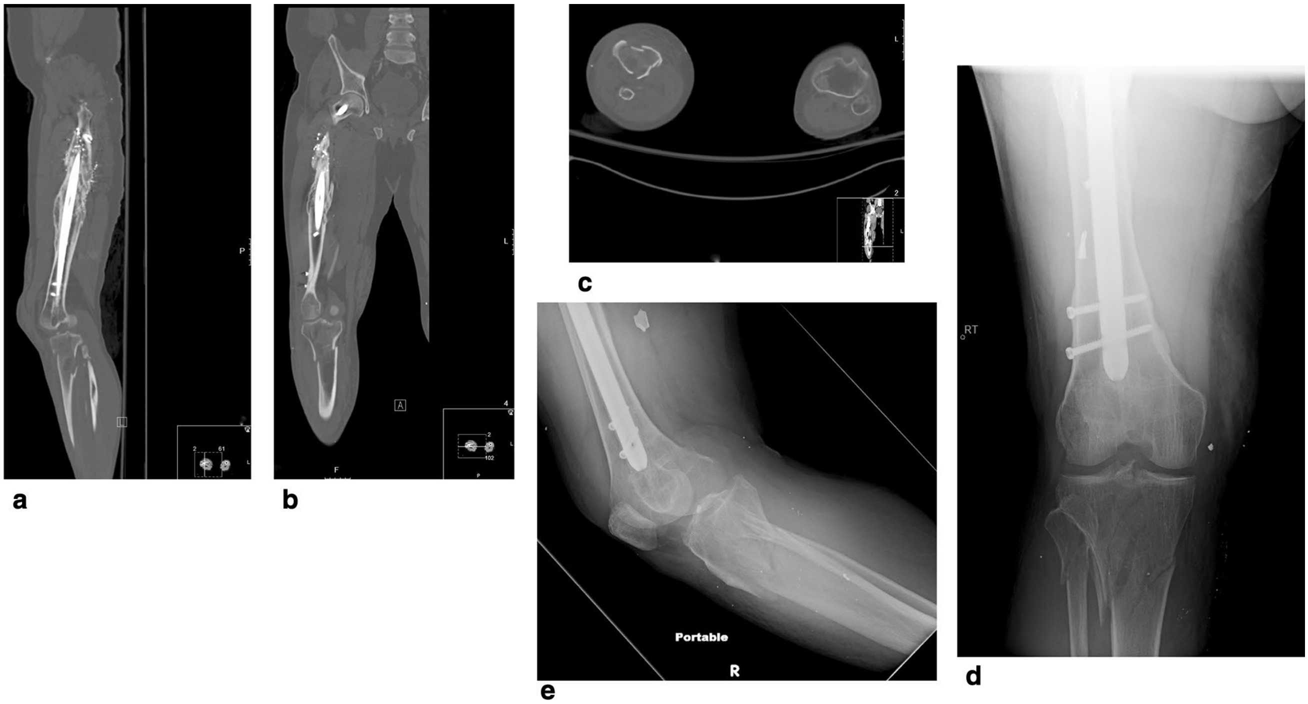


**Fig. 2** A typical Schatzker type VI fracture encountered in the study. Clockwise, from left: **a** sagittal, **b** coronal and **c** axial CT bone views. **d** AP and **e** lateral radiograph of right knee. All imaging prior to fixation

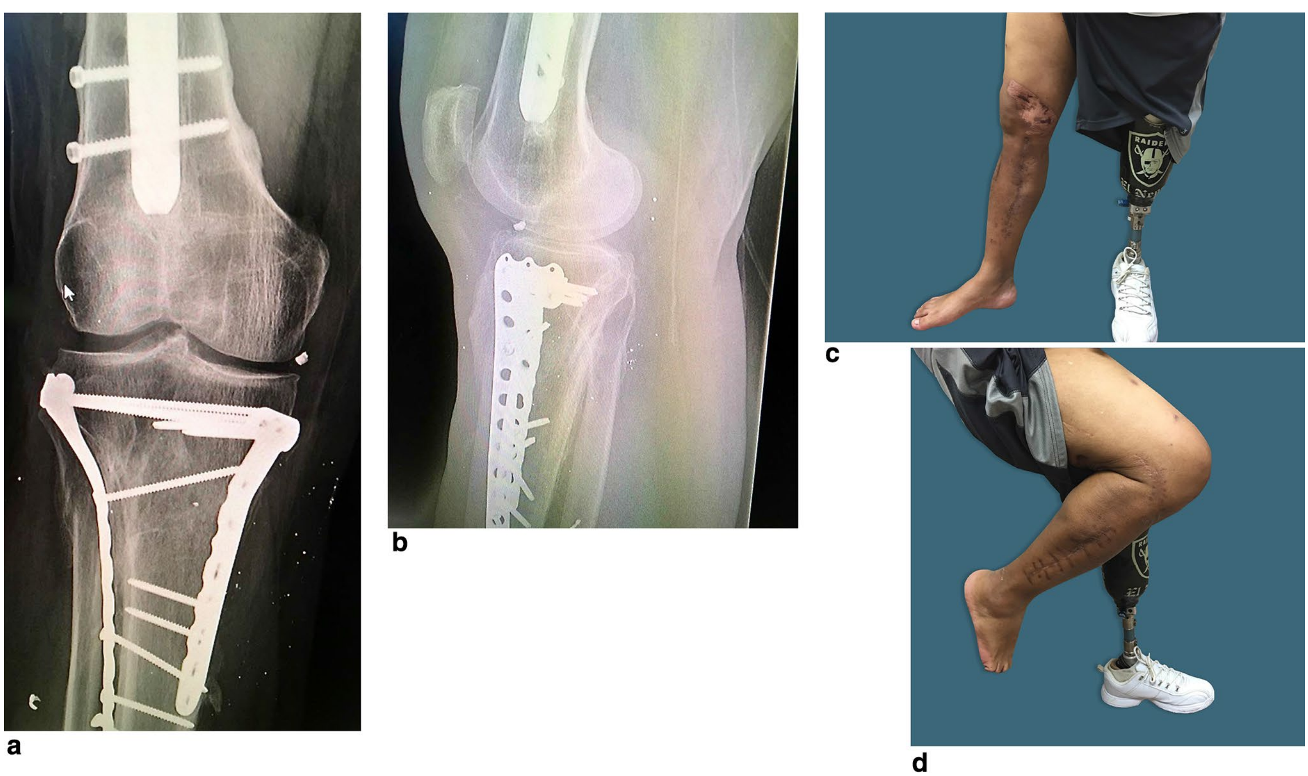


**Fig. 3** Results of previous patient. Clockwise, from left: **a** AP and **b** lateral radiographs showing plate and screw implants. **c** Medial and **d** lateral photographs showing healing and degree of knee flexion after fasciotomy and fixation

However, there are also studies that show no increased association with infection in this injury pattern. Hak and colleagues studied definitive internal fixation of tibial plateau fractures in the presence of open fasciotomy wounds and found that over 55 months, 14 patients received fasciotomies with no development of deep infection, while eight patients developed deep infection out of the 128 patients who did not receive fasciotomy [22]. Egol and colleagues, in their prospective study on the staged management of proximal tibia fractures, were not specifically evaluating compartment syndrome, but found only one out of 10 compartment syndrome cases developed infection [23]. Ruffolo and colleagues found that the presence of compartment syndrome had no significant association on the rate of infection [24]. Barei and colleagues also found no association of compartment syndrome with the development of septic complications [25].

The study conducted by Zura focused on the timing of definitive fixation and infection rates in tibia plateau fractures. Examination of four-compartment fasciotomies in tibia plateau fractures showed no significant difference between definitive fixation with ORIF performed before, during, or after the definitive closure of the fasciotomy incision. The conclusion of this study states that definitive fracture treatment can be performed at the discretion of the attending surgeon based on surgeon preference and patient status without increasing the risk of infection [7]. This tactic is mirrored by our surgical staff in management of these patients.

The early detection of impending compartment syndrome is also essential for physicians. Further study is necessary to elucidate which patients will be at highest risk of developing ACS before clinical symptoms appear.

Nonunion was seen in one patient. Although this patient did achieve union at 48 weeks without the need for operation, the time to union exceeded the definition of when union is considered acceptable. This individual also had diabetes and hypertension. Two patients had delayed union; one of whom also had infection of their tibial plateau. The delayed healing of the fracture could be related to a variety of factors including the high-energy trauma, extensive soft tissue damage, infection of the fracture site, and extensive soft tissue dissection during definitive fixation. Union was still achieved without the need for further surgical intervention. Union was also achieved without further intervention in the patient with the femoral implant; the delayed healing may have been due to reduced weight-bearing or alternative distribution of force due to the implant, resulting in lower mechanical stress.

Nonunion is a complication that can cause tremendous hardship for a patient, often requiring revision surgery and resulting in disability or lasting pain [5]. Blair and colleagues reported 9% (2/23) of patients with compartment syndrome developed nonunion in their study, but there was no significant difference in the rate of nonunion compared to the control group [18]. Ruffolo and colleagues described a nonunion rate of 10% (14/140) in their study of high-energy bicondylar tibial plateau fractures, but they found compartment syndrome was not a risk factor for developing nonunion [24]. Conversely, in the review article by Reverte and colleagues, an increased rate of nonunion or delayed union was found in the group with tibial fracture plus compartment syndrome, 45% (107/238), compared to the control group with only tibial fracture, 19% (79/418) [26]. However, their analysis included studies of tibial shaft fractures, not solely tibial plateau fractures, as well as patients under 18 years old. The results for this study suggest a low rate of nonunion associated with ACS and tibial plateau fractures.

### Limitations

This study is not without limitations. It has no control group, a small sample size, and four patients were lost to follow-up. The small sample size also limits the power of this study.

## Conclusion

Acute compartment syndrome is a limb-threatening condition. Fasciotomy may increase the risk of postsurgical site infection. Data from this study demonstrated that the infection rate was lower than in other recently published studies. The incidence of delayed union and nonunion of the fracture was also lower than what has been recorded in the literature for this fracture type. This study contradicts the widely held view that acute compartment syndrome results in an increased risk of infection or nonunion. We believe that performing early decompression does not significantly increase the risk of infection or nonunion of the fracture, but future prospective studies are needed.

**Acknowledgements** Thanks to Emmanuel Eisenstein, MD, for his advice and assistance with radiographic review. Thanks to Mohammad Rauf-Afzal for his statistical analysis.

**Authors' contribution** All authors take full responsibility for the content of the manuscript and vouch for its veracity.

**Compliance with ethical standards**

**Conflicts of interest** The authors declare that they have no competing interests.

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