Early Open Reduction and Internal Fixation of Acute Low-Energy Tibial Plateau Fractures Does Not Increase the Rate of Perioperative Complications

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ABSTRACT

Introduction: The treatment algorithm for tibial plateau fractures continues to evolve as surgeon experience increases. Initial surgical procedures have been fine-tuned over time.

Methods: This is a retrospective chart review of 132 patients with low-energy tibial plateau fractures (Schatzker I–IV) treated at a level-1 academic trauma center between January 2008 and February 2018. This study analyzes patient outcomes managed with primary operative intervention within 48 hours of admission. The average age was 45 years (range, 19 to 84 years). There were 92 men and 40 women. Statistical analysis focused on comparisons between historical complication rates and the findings of this study. The study was powered for short-term outcomes (1- to 3-month follow-up), with a few select patients followed-up with for 12 to 15 months. Study variables consisted of length of hospital stay, age, and time to follow-up.

Results: The average length of stay was 4.68 days with an overall complication rate of 10.6%. Complications included infections (6.06%), compartment syndrome (1.52%), persistent pain and stiffness (1.52%), and other causes (1.52%). There were no statistically significant differences when compared to complication rates cited in the literature ($P > 0.05$).

Conclusion: Although the optimal timing of treatment for tibial plateau fractures remains debatable, it is clear that early surgical intervention provides the advantage of immediate repair. Our data shows that Schatzker fractures (I–IV) may be safely operated on within 48 hours without a significant increase in complications. Early surgical intervention provides several advantages, including easier anatomical reduction, speedier recovery, reduced hospital length of stay, and reduced cost.

Keywords: Tibial Fractures, Postoperative Complications, Open Fracture Reduction, Fracture Fixation, Perioperative Care

INTRODUCTION

The tibial plateau is a critical load-bearing area in the human body. Fractures of the tibial plateau affect knee joint alignment, stability, and motion,[1] with an incidence of 10.3 per 100,000 annually.[2] Multiple classifications of tibial plateau fractures have been developed to assess injury severity, create appropriate treatment plans, and predict clinical prognosis. The Schatzker,[3] Hohl,[4] Moore,[5] and AO classifications are the most used systems for this type of fracture.

Sir Astley Cooper first described proximal tibial fractures in 1825.[6] Astley treated most minimally displaced fractures with realignment splintage and early mobilization.[6] Sarmiento popularized functional cast bracing of most tibial condylar fractures,[7] and Rasmussen introduced open reduction and internal fixation (ORIF) of this fracture class.[8]

Methods and implants of internal fixation of this fracture have improved, and ORIF has become more common. Initial comparisons of closed and open treatment showed similar results.[9-11] However, ORIF has become well accepted for displaced fractures, and indications have expanded.[3,7,12-14] Although early external fixation followed by delayed internal fixation has been widely adopted for high-energy bicondylar fracture types,[15-17] there is a scarcity of literature guiding management and optimal timing of surgical fixation for low-energy tibial plateau fractures. Recent data trends have favored acute operative intervention because it allows for an overall facilitated anatomical reduction and offers earlier patient mobilization, increased range of motion, and likely improved recovery.[18-20] Early studies comparing immediate-to-delayed intervention showed reduced infection rates and perioperative damage with delayed surgery, which is attributed to the quelling of soft-tissue inflammation when sufficient time before intervention is allotted.[15-17] When surgery is delayed, there are risks, including infection, wound breakdown, loss of fracture reduction, and higher rates of failure of internal fixation.[19,20]

There is great benefit in reducing hospitalization time because it effectively correlates with faster recovery, early return to work, and reduced cost.[18,21] Increased hospital stay can hinder the opportunity for mobility and early rehabilitation while increasing the rate of nosocomial infection and other iatrogenic complications.

This study aimed to analyze postoperative trends over the past 10 years that support the notion that the benefits of immediate surgery were attainable, while overall perioperative complication rates remain unchanged.

METHODS

After receiving Institutional Review Board approval (TTUHSC #E18091), we retrospectively identified 1200 trauma patients with tibial plateau fractures. Inclusion criteria consisted of 18 years or older patients with low-energy fractures (Schatzker I-IV) treated within 48 hours of presentation. Exclusion criteria included patients with high-energy tibial plateau fractures (Schatzker V–VI), open tibial plateau fractures, any category tibial plateau fracture treated by external fixation with delayed internal fixation, or those with interventions after 48 hours. A total of 132 of 1200 patient charts met the criteria. Study variables consisted of the duration of hospital stay, age, and time to short-term follow-up (1 to 3 months), with identification and classification of complications.

Statistical Method

Demographic data were summarized using descriptive statistics. To test for statistical significance, 2-tailed Chi-Square analyses were performed using IBM SPSS Statistics Software (IBM Corporation; Armonk, NY). The focus was placed on comparing complication rates to historical data, which were calculated separately and as a composite for each follow-up period. Complications were further classified into sub-groups, including infections, persistent joint pain and stiffness, compartment syndrome, and other perioperative complications.

RESULTS

Patient demographics included 92 men and 40 women with an average age of 45 years (range, 19 to 84 years). In most cases, patients presented with isolated fractures (82 patients, 62.1%) versus polytrauma (50 patients, 37.9%). Cases classified by fracture type are summarized in Table 1.

Table 1. *Demographic Data by Age, Sex, and Fracture Type*

	Early treatment (n=132)
Mean Age (Range)	45 (19 - 84)
Sex (Male/Female)	92/40
Schatzker 1	31
Schatzker 2	58
Schatzker 3	30
Schatzker 4	13
Number of Complications (18-49 years)	9
Number of Complications (50+ years)	5

The average length of hospital stay following definitive, operative treatment was 4.68 days (range, 0.51 to 13.5) from time of presentation. There were 14 complications (10.6%), with the majority occurring in the younger age group (18 to 49 years) (Figure 1).

The overall infection rate was 6.06%. A total of six patients developed a superficial infection that resolved within 1-week postoperatively with oral antibiotics. Two patients developed deep-tissue infections. In the first patient, early signs of infection became apparent at 3-week follow up. Clinical symptoms consisted of impaired wound healing with purulent discharge, erythema, and hyperthermia. *Staphylococcus aureus* was identified. The patient was readmitted and taken back to the operating room for debridement with implant retention, followed by 6 weeks of intravenous antibiotics. He had an uneventful 12-month follow-up. The second patient demonstrated signs of deep infection 4 weeks postoperatively. There were no clinical signs of inflammation, but the patient reported vague chronic pain. Plain radiographs revealed signs of periosteal reaction. The patient was diagnosed with chronic osteomyelitis attributed to *Staphylococcus epidermidis* that was ultimately addressed with hardware removal and external fixation.

One patient developed bilateral pulmonary emboli 5 days postoperatively, which was treated with therapeutic anticoagulation. At 6 months follow-up, the patient reported multiple bouts of lower-extremity deep venous thrombosis.

One patient experienced acute patellar tendon rupture postoperatively. The integrity of the tendon was compromised as a result of the presenting trauma, making the initial surgery difficult to perform. The complication was addressed through primary repair of the tendon. However, at 5 weeks follow-up, the patient demonstrated tenderness and swelling at the inferior pole of the patella, which is suggestive of patellar tendon re-rupture. Further inquiry revealed poor compliance with bracing and physical therapy.

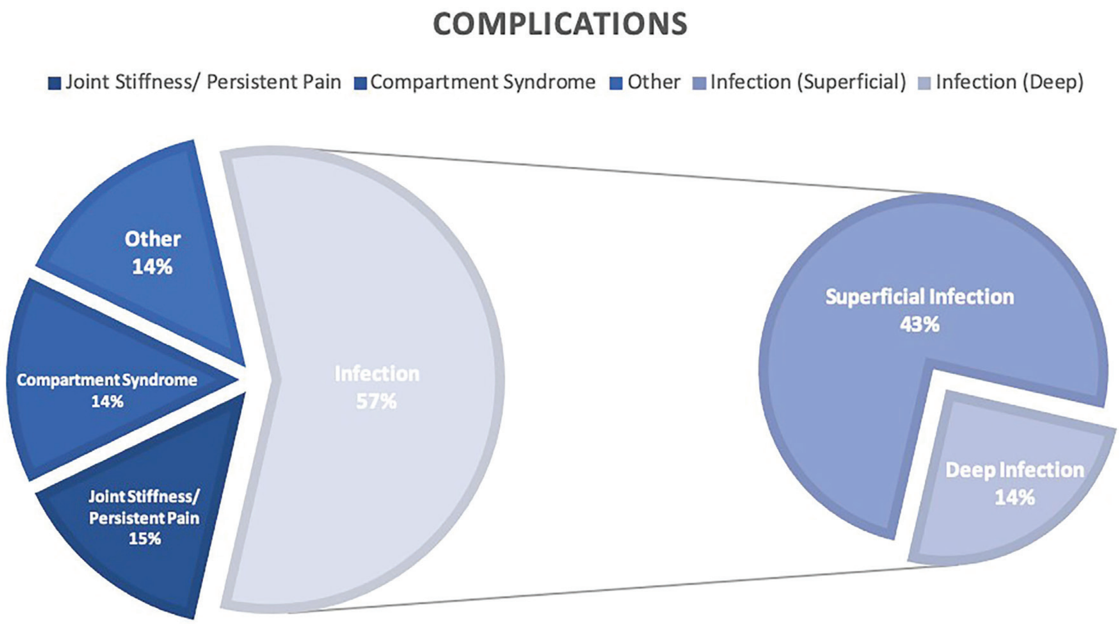

Figure 1. *Charts showing the distribution of complications.*

After the second surgical repair, the patient was immobilized in a long-leg cast in extension for 6 weeks with partial weight bearing using crutches. Intensive physical therapy was prescribed. The patient returned to baseline activity at 6 months follow-up.

Two patients developed compartment syndrome. One of the patients developed compartment syndrome preoperatively while awaiting surgery, and the other patient developed it approximately 18 hours postoperatively. There were no lasting complications in this group at 3- and 6-month follow-up.

Finally, two patients had concerns of persistent postoperative pain and stiffness with only mild improvement at a mean time of 6 months (range, 5 months to 7 months). Joint stiffness was defined as subjective pain and discomfort reported by the patient and evidence of decreased range of motion or radiographic evidence of arthritis. One of these patients developed persistent knee stiffness that was thought to be related to hardware misalignment, for which revision surgery was offered at 5-month follow-up. The other patient developed arthrofibrosis detected at their 7-month follow-up with arthroscopic lysis offered. Both patients ultimately declined revision procedures.

DISCUSSION

Time is a consideration that directly influences the surgical outcomes of low-energy tibial plateau fractures. A study that exclusively examined Schatzker fractures (type IV-VI) found that when early internal fixation is feasible, it could effectively shorten the length of hospital stay, decrease the cost of hospitalization, and promote early functional rehabilitation.[22]

One study compared outcomes between immediate and delayed ORIF of tibial plateau fractures in skiing and snowboarding trauma patients. The study showed that patients treated immediately (defined as less than or equal to 24 hours postinjury) had significantly fewer occurrences of compartment syndrome (3.0% vs 27.0%), needed fewer fasciotomies (6.0% vs 31.0%), and had a shorter average length of stay (3 days vs 6.5 days). These results were all statistically significant ($P < 0.05$).[18]

The Dedicated Orthopaedic Trauma Room (DOTR) model is worth mentioning because it provides the framework to maximize the operating room, staff, and resource availability, allowing for the timely completion of the cases outlined in this study. This model delineates an operating room scheduling system that prioritizes urgent trauma and strategically allocates support staff, resources, and experienced trauma personnel. Research documenting the spread of this model to multiple institutions over the past 10 years has demonstrated consistent improvement in patient outcomes, including decreased length of stay, improved rehabilitation, and patient satisfaction.[23]

Infections

Infection-related sequelae have been attributed to extensive soft-tissue tearing from diffuse inflammation during early operative intervention.[24,25] The treatment of tibial plateau fractures has evolved dramatically over the last 20 years, with greater attention to protecting the soft-tissue envelope.[26] Our study featured an overall infection rate of 6.06% observed at short-term (1 to 3 months) follow-up with the more complicated cases followed for longer periods. Papagelopoulos et al[27] estimated that the infection rate among treated tibial plateau fractures lies between 2.0% to 13.0%. This number is derived from a range of studies featuring both urgent and delayed surgical interventions.

Table 2. Summarized infection rates as per Zhao et al[1]

Study	ORIF	External Fixation
Total Infections		
Boston (1994)[2,3]	42.9%	50.0%
Krupp (2009)4	7.1%	13.3%
Guryel (2010)5	2.5%	0.0%
Chan (2012)6	12.5%	25.7%
Jansen (2013)7	9.5%	100.0%
Ahearn (2014)8	4.7%	28.6%
Pun TB (2014)9	0.0%	16.7%
Conserva (2015)10	15.8%	12.2%
Total	8.3%	16.8%
Surgical Infections		
Study	**ORIF**	**External Fixation**
Boston (1994)2,3	0.0%	50.0%
Krupp (2009)4	3.6%	6.7%
Guryel (2010)5	2.5%	0.0%
Chan (2012)6	12.5%	17.1%
Jansen (2013)7	9.5%	50.0%
Ahearn (2014)8	2.9%	28.6%
Pun TB (2014)9	0.0%	16.7%
Conserva (2015)10	5.3%	7.3%
Total	4.6%	12.8%
Deep Infections		
Boston (1994)2,3	42.9%	0.0%
Krupp (2009)4	3.6%	6.7%
Guryel (2010)5	0.0%	0.0%
Chan (2012)6	0.0%	8.6%
Jansen (2013)7	0.0%	50.0%
Ahearn (2014)8	2.9%	0.0%
Pun TB (2014)9	0.0%	16.7%
Conserva (2015)10	10.5%	4.9%
Total	**3.8%**	**5.1%**

Literature that focused exclusively on ORIF without external fixation estimated a similar incidence of infectious wound complications, reportedly in the range of 5.0% to 15.0%.[28] The findings of historical data trends compared to the data obtained in this present study revealed no statistically significant difference in infection rates ($P > 0.05$).

Zhao et al[29] constructed a meta-analysis with an extensive look at common complications associated with tibial plateau fractures. They separated the analysis into two groups: ORIF versus external fixation with or without surgical intervention. Although it featured a collection of data that encompassed a complete gradient of Schatzker-classified fractures, it had a higher propensity of Schatzker types (V–VI). However, it did not exclusively organize data by time, as this pool of data consisted of immediate and delayed ORIF versus external fixation with delayed intervention (Table 2). The infection rates between the outlined studies that were managed exclusively by ORIF (both delayed and immediate) described in this meta-analysis and our study were determined not significantly different via 2-tailed Chi-Square analyses ($P = 0.56$). However, when we compared overall infection rates and subtyped superficial infection rates in the "external fixation" group, we determined the existence of statistically significant findings. External fixation with delayed or no surgical intervention had a higher propensity of infection ($P = 0.01$) and superficial infections ($P = 0.02$) (Table 3). Perhaps this can be attributed to this meta-analysis focusing primarily on Schatzker types V through VI instead of our data collection featuring Schatzker types I through IV.

Table 3. Comparison of infection rates between this current study and Zhao et al[1]

Complication	Current Study	Zhao et al	*P*-value
Statistical Significance Summarized (ORIF vs ORIF)			
Infection	6.06%	8.00%	0.56
Superficial	4.54%	5.00%	0.99
Deep	1.52%	4.00%	0.16
Statistical Significance Summarized (ORIF vs External Fixation)			
Complication	Current Study	Zhao et al	*P*-value
Infection	6.06%	17.00%	0.01
Superficial	4.54%	13.00%	0.02
Deep	1.52%	5.00%	0.16

Compartment Syndrome

Compartment syndrome is an important, often underappreciated complication. As stated in the literature, the risk of compartment syndrome appears to be highest among high-impact (Schatzker V–VI) tibial plateau fractures and fracture dislocations, but it can also occur in any class of tibial plateau fracture. Complications associated with compartment syndrome can be devastating because they can result in the loss of function and limbs, with prolonged recovery with limited regain of function.[30-32] Generally, the literature lacks concrete treatment strategies for severe tibial plateau fractures. However, most studies favor early external fixation with delayed internal fixation.[33-35] Recent studies suggest that this practice may contribute to intramuscular pressure by lengthening the limb and reducing myofascial compartment volumes. If compartment syndrome occurs in this patient population, the fasciotomies must be planned carefully. Incorrectly placed fasciotomy wounds may compromise future attempts of ORIF, especially in delayed management.[36]

Table 4. *Rates of compartment syndrome compared between this current study, Zhao et al[1] and Janes et al[2]*

Compartment Syndrome		
Current Study		***P*-value**
Participants	132	--
Percentage of compartment syndrome (ORIF)	1.52%	--
Zhao et al		
Participants (External Fixation)	37	
Percentage of compartment syndrome (External Fixation)	5.41%	0.4785
Participants (ORIF)	45	--
Percentage of compartment syndrome (ORIF)	8.89%	0.0797
Janes et al		
Participants (Immediate ORIF)	93	--
Percentage of compartment syndrome (Immediate ORIF)	3.00%	0.6906
Participants (Delayed ORIF)	26	--
Percentage of compartment syndrome (Delayed ORIF)	27.0%	< 0.05

ORIF, open reduction internal fixation
1. Zhao XW, Ma JX, Ma XL, et al. A meta-analysis of external fixation versus open reduction and internal fixation for complex tibial plateau fractures. Int J Surg. 2017;39:65-73.
2. Janes PC, Leonard J, Phillips JL, et al. Skiers and snowboarders have improved short-term outcomes with immediate fixation of tibial plateau fractures. Trauma Surg Acute Care Open. 2017;2(1):e000119.

Urgent internal fixation can effectively prevent compartment syndrome because the injury is repaired before swelling has peaked, causing the soft tissue to be the most compromised. It can also prevent the adverse effects of external fixation with delayed internal fixation. Janes et al[18] compared the incidence of compartment syndrome in early versus delayed ORIF fixation (3.0% vs 27.0% respectively), with early ORIF having significantly lower occurrences of this complication. In this study, "immediate" was defined as a surgical intervention within 24 hours of presentation. Our current study had a low incidence of compartment syndrome (1.52%), which was not significantly different compared to the immediate surgical intervention group of this study ($P > 0.05$) (Table 4).[18]

Joint Stiffness and Limited Range of Motion

Joint stiffness with reduced knee motion is common and can compromise the outcome of tibial plateau fractures treated with operative fixation. Loss of knee range of motion is thought to result from damage to the extensor retinaculum attributed to presenting trauma or surgical exposure. Papagelopoulos et al[27] attribute the main mechanism of reduced mobility and stiffness to extensor scarring, with (or without) arthrofibrosis of the knee or patellofemoral joint. Other studies have suggested damage results from prolonged immobilization after fracture or internal fixation. Immobilization of the knee for periods of more than 3 or 4 weeks has often been linked to frequent patient outcomes reporting some degree of permanent stiffness.[27] Timely surgical intervention with a shorter hospital course, rapid transition to weight bearing status, and increased mobility are reasons to support early surgical intervention. In reference to Zhao et al,[29] the incidence of joint stiffness in the "ORIF" subgroup compared to the findings of the current study demonstrated no significant difference ($P>0.05$). There was a significant difference in rates compared to groups managed by external fixation and delayed surgical intervention. These findings are summarized below in Table 5.

Table 5. *Incidence of joint stiffness as per Zhao et al[1] compared to the findings of the current study*

Joint Stiffness		
Current Study		***P*-value**
Participants	132	--
Percentage of joint stiffness (ORIF)	1.52%	--
Zhao et al		
Participants (External Fixation)	71	--
Percentage of joint stiffness (External fixation)	9.86%	0.0165
Participants (ORIF)	66	--
Percentage of joint stiffness (ORIF)	1.52%	1.0000

ORIF, open reduction internal fixation
1. Zhao XW, Ma JX, Ma XL, et al. A meta-analysis of external fixation versus open reduction and internal fixation for complex tibial plateau fractures. Int J Surg. 2017;39:65-73.

Approach to High-Energy Tibial Plateau Fractures

While the two-step approach has become the standard of care for high-energy tibial plateau fractures, no specific guidelines exist. Most providers recommend a thorough evaluation of the soft tissues in all patients presenting with tibial plateau fractures before deciding if urgent surgical intervention can be tolerated. Such judgments are difficult to quantify because they largely depend on operator experience and the visual integrity of the affected limb. In cases of uncertainty, a staged protocol employing provisional stabilization with an external fixator is traditionally recommended to maintain length and alignment and facilitate soft-tissue healing.[37,38] Despite the benefit in reduced infection rated and improved soft-tissue healing, there is growing evidence of adverse events, such as prolonged treatment course, muscular atrophy, and joint stiffness at the fracture site that ultimately impacts functional rehabilitation.[19,20] Simpler fractures (Schatzker I–IV) often have a less severe soft-tissue injury and may benefit from immediate surgical intervention.[39] In our study, we found no statistically significant difference in the overall perioperative complication rate in low-energy trauma patients surgically treated within 48 hours versus those managed with delayed intervention.

Case Report

A 46-year-old man presented to the emergency department with a right leg tibial plateau fracture (Schatzker VI) following a motor-vehicle collision. Imaging revealed a comminuted fracture of the proximal third of the tibial diaphysis with superior extension into the metaphysis (Figures 2 and 3). The lateral depression was 1.5 cm, and the patient underwent ORIF within 14 hours. A 13-hole plate was placed on the anterolateral aspect of the tibia. Distally, a combination of regular and locking screws was placed. Proximally, one regular screw and three locking screws were used (Figure 4). Synthetic bone graft and calcium triphosphate were applied at the tibial plateau region. A prophylactic fasciotomy of the anterolateral compartment was performed to reduce the risk of compartment syndrome, followed by skin closure. Plain radiographs were taken postoperatively (Figures 5 and 6). There

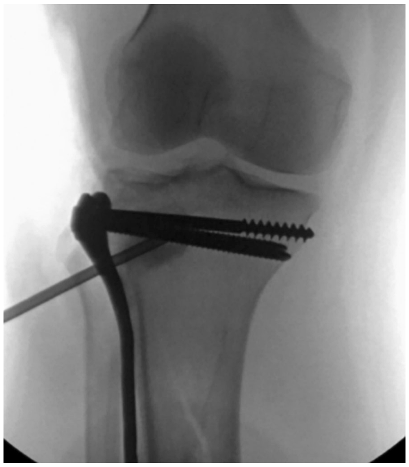

Figure 4. *Intraoperative fluoroscopy image of the tibial plateau with screws placed to correct depression of lateral tibial plateau.*

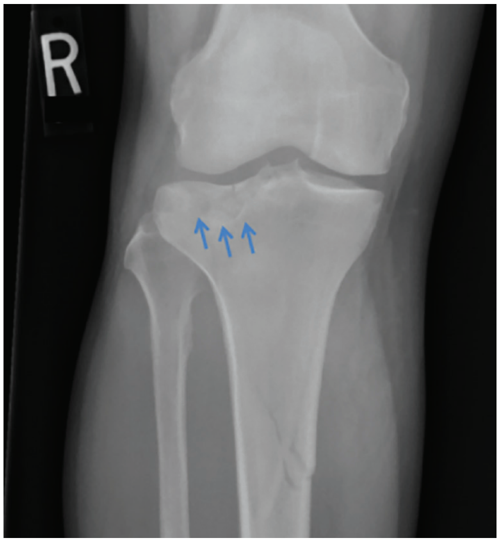

Figure 2. *X-ray of patient's right leg showing a Schatzker type VI tibial plateau fracture on the day of injury.*

Figure 3. *Computed tomography scan of patient's right leg showing Schatzker type VI tibial plateau fracture on the day of injury.*

Figure 5. *Postoperative anteroposterior x-ray.*

Figure 6. *Postoperative lateral x-ray.*

Figure 7. *Patient's x-ray at 3-month follow-up showing intact plate and screws, good alignment, and proper healing.*

Figure 8. *X-ray at 2-year follow-up showing a well aligned and healed tibial fracture with proper joint alignment and no evidence of hardware loosening or breakage.*

were no immediate complications after surgery, and the patient was discharged home with a knee immobilizer and non-weight bearing status. At 1-week follow up the patient's motor and sensory function was intact. There was appropriate postoperative swelling with no signs of infection. He initiated range of motion exercises and physical therapy. At his 6-week follow-up, he started at 25.0% partial weight bearing with progression to full weight bearing status. At his 3-month follow-up, he was using a cane to assist with ambulation. He could fully extend the right knee with approximately 110° of flexion. Radiographs showed intact plate and screws, good alignment, and fracture line with proper healing (Figure 7). At 2 years postoperatively, the patient regained full function. X-rays demonstrated a well-healed fracture with proper joint alignment and no evidence of hardware loosening or breakage (Figure 8).

Limitations and Considerations

Patients were generally followed 1 to 3 months postoperatively, with a select few followed up to 24 months. We would have liked to track patient data for up to 12 months postoperatively across the board. However, given the hospital's unique location, most outpatient follow-up was completed at sites outside the hospital's network. Longer-term follow-up data could reveal a higher-than-usual complication rate. Data were obtained from a level-1 trauma center located along the United States-Mexico border, with a preference for Hispanic and Mexican-American patients. Data may not be generalizable to other ethnic groups.

Other considerations include an in-depth analysis of the use of peripheral nerve blocks in our patient population. Given its relative modern outlook, it was not included in this study. However, it is worth noting that its implementation in patients with tibial plateau fractures has positively impacted outpatient management by decreasing perioperative opioid use, hospital length-of-stay, and other iatrogenic complications. It would be worth analyzing and implementing such trends moving forward because they could potentially magnify the impact of the findings of this study.[40]

CONCLUSION

We have observed that many low-energy fractures may be safely operated within the first 48 hours without a significant increase in complication rates. The orthopaedic surgeon should base their approach on both fracture pattern and soft-tissue integrity. Further investigative efforts are warranted to solidify current advancements of optimal treatment of tibial plateau fractures.

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