Skiers and snowboarders have improved short-term outcomes with immediate fixation of tibial plateau fractures

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ABSTRACT
Background Tibial plateau fractures (TPFs) are frequently associated with motor vehicle accidents, auto-pedestrian crashes and falls. However, hospitals near ski resorts commonly treat TPF resulting from skiing. The soft tissue envelope and original mechanism of injury are important determinants in the decision to proceed with immediate or delayed fixation of the fracture. Our objective was to assess whether immediate (≤24 hours) versus delayed (>24 hours) open reduction internal fixation (ORIF) affected in-hospital outcomes among snow sport participants.

Methods This was a retrospective study of patients with isolated TPF who were injured while skiing or snowboarding and treated at a Level III Trauma Center that serves four major ski resorts between 2010 and 2013. Clinical characteristics and in-hospital outcomes were obtained from an existing trauma database. Imaging was reviewed to classify the fracture as high (Schatzker IV–VI) or low (Schatzker I–III) energy. Differences in clinical characteristics and outcomes between immediate and delayed ORIF patients were analyzed with χ² and Wilcoxon two-sample tests. These analyses were also performed in the high-energy and low-energy fracture populations.

Results ORIF was performed on 119 snow sport patients, 93 (78%) immediately. Patients had a median age of 49 years (range 19–70) and were predominantly male (66%). Forty percent sustained a high-energy TPF. No differences were observed between the demographic characteristics, injury severity, Schatzker scores or time from injury to hospital arrival for patients treated immediately versus delayed treatment. Compared with delayed fixation, patients treated immediately had less compartment syndrome (3% vs 27%), needed fewer fasciotomies (6% vs 31%) and had a shorter length of stay (3 vs 6.5 days), p<0.05 for all. These results persisted in the stratified analysis of high-energy fracture patients.

Discussion Treating patients immediately led to more favorable in-hospital outcomes compared with delayed treatment, even among the patients with a high-energy fracture.

Level of evidence Level IV, Therapeutic/Care Management.

BACKGROUND
Proximal tibial plateau fractures (TPFs) account for approximately 1% of all fractures in the USA.12 The fracture occurs through varus and/or valgus stress applied through axial loading3 and can result in articular depression, comminution, malalignment and soft tissue (ligamentous and meniscal) damage of the proximal tibia. This fracture is most frequently associated with motor vehicle and motorcycle accidents, auto-pedestrian crashes and falls, while only 3%–9% occur from sports-related injuries.4–12

It is common for hospitals serving regions near ski resorts to treat TPF ensuing from snow sports. Skiing can be a high-velocity sport that creates sudden forces to the knee through the ski, boot and binding systems. In 1980, TPF accounted for 1% of knee injuries among skiers.13 In Finland, data from four trauma centers near ski resorts were examined to classify tibial fracture patterns due to skiing; the proximal tibia was the second most common fracture location, accounting for 27% of the tibial fractures. The authors stated that their most important finding was the relatively high number of TPFs among adult skiers.14

Management of TPF is determined by the severity of fracture, soft tissue damage and open versus closed fractures. When surgery is necessary, the current standard for definitive treatment is open reduction internal fixation (ORIF).1 The timing from injury to ORIF remains controversial. The status of the soft tissue envelope and the original mechanism of injury are both important determinants in the decision to proceed with immediate versus delayed ORIF. Some orthopedic surgeons favor delayed internal fixation to provide healing time for the soft tissue envelope, which decreases compromise of the soft tissue and chance of infection.15 16 Others believe immediate ORIF is advantageous to reduce further soft tissue damage from continued swelling, reduce the risk of compartment syndrome and subsequent multiple procedures, promote early rehabilitation and decrease hospital length of stay (LOS) and cost.4 17

The objective of the present study was to examine patients who sustained isolated TPF from alpine snow sports, in order to compare short-term, in-hospital outcomes between patients who underwent immediate (≤24 hours post-injury) and delayed ORIF (>24 hours post-injury).
Figure 1  Flow chart showing the inclusion criteria for patients with tibial plateau fracture treated with open reduction internal fixation (ORIF).
were snowboarders and 109 (92%) were skiers. No differences were observed between the demographic characteristics, injury severity or time from injury to hospital arrival for patients with an isolated TPF treated immediately versus delayed (Table 1).

We found that the skiers were more likely to fracture their tibial plateau in a twisting or tumbling fall from the same level (42%), whereas the snowboarders were more often injured in collisions (50%) or jumping and terrain park activities (40%), p=0.001 (Table 2). Although the mechanism of injury differed between the skiers and snowboarders, neither the fracture classifications nor the timing to ORIF was significantly different; as such, the skiers and snowboarders remained grouped together for the remaining analyses.

Table 1 also compares the in-hospital outcomes between patients treated with immediate and delayed ORIF. Immediate ORIF was associated with more favorable in-hospital outcomes than delayed ORIF: the incidence of compartment syndrome was significantly lower (3% vs 27%, p=0.001); patients were more likely to have only one visit to the OR (96% vs 54%, p<0.001); when more than one visit to the OR was needed, the immediate group experienced a maximum of three visits versus seven for the delayed group; patients were more frequently discharged home (100% vs 92%, p=0.04); hospital LOS was shorter (3 vs 6 days, p<0.001); fewer patients received a fasciotomy (7% vs 31%, p=0.002).

Table 2 reports the timing of the fasciotomy procedure and compartment syndrome diagnosis for 14 patients who received a fasciotomy. Fasciotomies were performed preemptively in four patients (three immediate, one delayed). In the remaining 10 patients, a fasciotomy to manage compartment syndrome was performed prior to ORIF in five patients (all delayed) and on the same day as ORIF in five patients (three immediate, two delayed). One patient in the immediate ORIF group required a second fasciotomy. There were no in-hospital deaths, admissions to the ICU or infections.

The analysis was stratified to examine the characteristics and outcomes of patients with high-energy fractures separately from those with low-energy fractures. Table 4 shows that patients with high-energy fractures who had immediate ORIF had significantly better outcomes (fewer trips to the OR, decreased incidence of compartment syndrome, fewer fasciotomies performed, as well as shorter hospital LOS) than with delayed ORIF. In the low-energy fracture group, those treated immediately had significantly fewer trips to the OR and a shorter hospital LOS; there were no differences in the incidence of compartment syndrome or need for fasciotomy.

Overall, the immediate fixation population had procedures initiated well within the 24-hour window and were performed at a median of 6.9 hours. A post hoc analysis was performed to evaluate our definition of immediate as ≤24 hours after injury. We compared ORIF at <12 hours, 12–24 hours and >24 hours after injury and found the same differences in outcomes; the <12 and 12–24 hour groups were not statistically different from one another and had more favorable outcomes than those with ORIF after 24 hours.

DISCUSSION

In patients with an isolated TPF from skiing or snowboarding, treating patients with ORIF immediately led to more favorable in-hospital outcomes compared with delayed treatment, even among the patients with a Schatzker score between IV and VI. Patients undergoing repair of their TPF within 24 hours of snow sport injuries experienced a lower incidence of compartment syndrome, fewer fasciotomies, more frequent discharge to home and a shorter hospital LOS.

These findings are in agreement with several studies. Tang et al found that, under certain circumstances, early internal fixation of Schatzker IV–VI TPFs is feasible and decreased hospital stay, cost and promoted early functional rehabilitation. Benirschke et al believed that, with meticulous soft tissue techniques, definitive fixation as the initial procedure can be a safe management option for open complex plateau fractures.4

One reason immediate fixation may be efficacious is because the injury is repaired before swelling is maximized and the soft tissues compromised. A study by Xu et al suggested that optimal surgical timing is within 4 hours after trauma, when no obvious swelling exists; however, the authors felt it was difficult to complete the necessary imaging studies within 4 hours and therefore recommended 5–8 days as the optimal surgical timing.5 Tang et al hypothesized that a relatively mild swelling of the soft tissues around the TPF occurs within the first 12 hours after injury, making immediate fixation an option provided skin tension is not too high.6 In alpine skiers managed by both arthroscopic reduction with internal fixation and ORIF, Harris et al agreed that surgical timing is of critical importance and

![Figure 2](image_url)
noted that alpine ski injuries tend to be lower in energy, with minimal initial swelling, making same-day treatment a considerable option.31 These studies suggest that an early window exists in which ORIF can safely be performed, but if that window is exceeded, surgeons must wait for swelling and soft tissue injuries to subside. At the study hospital, anecdotally, it was not necessary to delay ORIF due to swelling for the majority of snow sport TPF. Despite the radiographic severity of some of these fractures, where 40% were classified as Schatzker IV–VI fractures and one-third were AO/OTA type C fractures, the soft tissues were often not compromised by an external force and were adequate to safely allow early, if not immediate, ORIF; 71% of the patients in our study had their ORIF performed within the first 12 hours after injury.

Still, some practitioners refuse immediate fixation in TPF.5 15 16 Egel et al supports the use of a temporary knee spanning external fixator, hence delaying internal fixation while allowing the soft tissue envelope to heal. Their study, consisting primarily of patients in motor vehicle crashes, found more favorable infection rates (5%)8 when utilizing the staged protocol as compared with historical controls, which reported complication rates between 13% and 88%. However, when we reviewed the historical control studies, we found that timing from injury to surgery was not reported,2 fixation techniques and hardware were attributed to some complications12 and prophylactic antibiotics were not used for the entire control study period.2 Though not specifically examined, a recent meta-analysis comparing external versus internal fixation for bicondylar TPFs found superficial infection to be higher in the patients treated with external fixation than ORIF (14.0% vs 4.7%; OR: 1.93, 95% CI 0.17 to 22.53, p<0.001); they found no difference in deep infection rate. The authors conclude that neither ORIF nor external fixation is superior in managing bicondylar TPFs; each procedure offers subtly different complications that orthopedics must be aware of, but external fixation does not offer a clear advantage over ORIF in avoiding soft tissue complications.22,23 Morris et al found a 14.2% rate of deep infection, despite staged fixation.23 Our results support the use of ORIF in avoiding soft tissue complications.22 Morris et al noted excellent long-term (mean 22.53, p=0.01); they found no difference in deep infection rate.

The primary limitation of our study is its retrospective nature and the inability to obtain follow-up data after the patients were discharged from the hospital, which prohibited the study of long-term outcomes. Other authors have studied long-term outcomes; Rademaker et al noted excellent long-term (mean 22.53, p=0.01); they found no difference in deep infection rate.
14 years) outcomes with the ability to regain activity as prior to their injury for patients with TPF treated with ORIF. Lobl et al assessed the ability of skiers treated surgically for TPF to resume physical activities and found that the majority could regain an active lifestyle after their injury (88%), though only 53% resumed skiing (mean follow-up time of 7.8 ± 1.8 years). Unfortunately, we do not have access to these data for our study population. Nevertheless, we were unable to study the effect of high-energy versus low-energy trauma or immediate vs delayed ORIF on any outcomes occurring after discharge. Additionally, our results reflect the injuries and practices of a rural, mountain hospital frequented with isolated TPFs in snow sport participants. These results are applicable for alpine snow sport participants but may not be generalizable to the broader isolated TPF population. Finally, this study included multiple treating physicians, making it difficult to ascertain whether a patient was treated immediately or delayed due to physician preference or injury severity. High-energy fractures can be operated on initially if the skin and swelling have no serious abrasions, cuts or blisters and are therefore considered adequate for closure. There are some cases where the patient is not able to have immediate fixation and must be delayed. Unfortunately, the swelling/skin assessment was subjective to the treating physician, with no classification system consistently utilized by surgeons. Hence, we were unable to provide information on physician preference or the soft tissue swelling/skin assessment. Among snow sport participants with a TPF, a prospective study is warranted where the soft tissues are protected from additional injuries to provide information on physician preference or the soft tissue swelling/skin assessment. Among snow sport participants with a TPF, a prospective study is warranted where the soft tissues are protected from additional injuries to provide information on physician preference or the soft tissue swelling/skin assessment. Among snow sport participants with a TPF, a prospective study is warranted where the soft tissues are protected from additional injuries to provide information on physician preference or the soft tissue swelling/skin assessment. Among snow sport participants with a TPF, a prospective study is warranted where the soft tissues are protected from additional injuries to provide information on physician preference or the soft tissue swelling/skin assessment. Among snow sport participants with a TPF, a prospective study is warranted where the soft tissues are protected from additional injuries to provide information on physician preference or the soft tissue swelling/skin assessment. Among snow sport participants with a TPF, a prospective study is warranted where the soft tissues are protected from additional injuries to provide information on physician preference or the soft tissue swelling/skin assessment.
mechanism, 54%–93% (1-4) frequently seen in metropolitan trauma. We believe the relatively homogeneous and healthy population of snow sport participants sustaining an isolated TPF, combined with the facility’s ability to rapidly perform ORIF and the lack of an external force damaging the soft tissues, contributed to the favorable outcomes of immediate ORIF.

In conclusion, among skiers and snowboarders, immediate fixation of isolated TPF with ORIF was associated with improved in-hospital outcomes compared with delayed ORIF. These findings suggest that immediate repair of proximal TPF is warranted in this population, even with high-energy fractures.

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Contributors PCI conceived of the study, participated in its design and data collection, interpreted data and provided critical revisions. JL participated in the study design and literature search, performed the statistical analysis and drafted the manuscript. JLP participated in the literature search, data collection and data interpretation and provided critical manuscript revisions. KS participated in the study design and provided analysis guidance and critical manuscript revision. BJ, DSS and CWN provided critical manuscript revisions. DBO participated in the study design and provided critical manuscript revisions. All authors read and approved the final manuscript.

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