Trauma Surgery & Acute Care Open

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

Peter C Janes,[1,2] Jan Leonard,[3,4,5,6] Jennifer L Phillips,[1,2] Brent J Bauer,[7] Kristin Salottolo,[3,4,5,6] Denetta S Slone,[8,9] Charles W Mains,[6,10] David Bar-Or[3,4,5,6,9]

[1]Department of Surgery, St. Anthony Summit Medical Center, Frisco, CO, USA
[2]Vail-Summit Orthopaedics & Sports Medicine, Frisco, CO, USA
[3]Department of Trauma Research, Medical City Plano, Plano, TX, USA
[4]Department of Trauma Research, Swedish Medical Center, Englewood, CO, USA
[5]Department of Trauma Research, St. Anthony Hospital, Lakewood, CO, USA
[6]Department of Trauma Research, Penrose Hospital, Colorado Springs, CO, USA
[7]Department of Orthopaedic Surgery, Medical City Plano, Plano, TX, USA
[8]Department of Trauma Services, Swedish Medical Center, Englewood, CO, USA
[9]Rocky Vista University, Parker, CO, USA
[10]Department of Trauma Services, St. Anthony Hospital, Lakewood, CO, USA

**Correspondence to**
Dr David Bar-Or, Swedish Medical Center, Englewood, CO 80113, USA; dbaror@ampiopharma.com

Presented at the 2017 American Association for the Surgery of Trauma Annual Meeting; 2017 International Conference of the Society for Skiing Safety.

Received 15 June 2017
Revised 7 August 2017
Accepted 8 August 2017

## 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 $\chi^2$ 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.

**To cite:** Janes PC, Leonard J, Phillips JL, *et al*. *Trauma Surg Acute Care Open* 2017;**2**:1–6.

## BACKGROUND

Proximal tibial plateau fractures (TPFs) account for approximately 1% of all fractures in the USA.[1 2] The fracture occurs through varus and/or valgus stress applied through axial loading[3] 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.[5 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).

## METHODS

This retrospective cohort study examined adult patients (≥18 years) who underwent ORIF to repair a TPF between 2010 and 2013. Data were

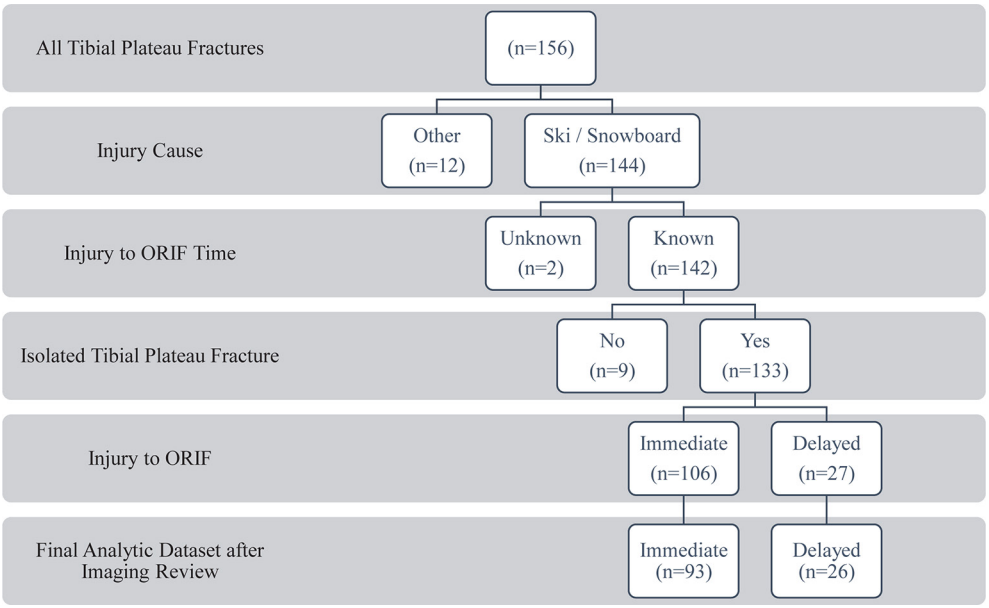


**Figure 1** Flow chart showing the inclusion criteria for patients with tibial plateau fracture treated with open reduction internal fixation (ORIF).

retrospectively obtained from a Level III Trauma Center that serves as the regional trauma center for four major ski resorts. Patients were identified from TraumaBase© (Conifer, Colorado), a trauma registry where dedicated registrars prospectively collect data on all traumatic injuries. Demographics, clinical characteristics, time between injury and ORIF and in-hospital outcomes were obtained from the trauma registry. Imaging was reviewed by three providers (PCJ, JLP, PJA) to evaluate the fracture patterns using the Schatzker[18] and AO/OTA[19] classification systems. This study was approved by the hospital's institutional review board.

The primary study population (figure 1) was identified by first using the International Classification of Diseases, ninth Revision (ICD-9) diagnosis codes for TPF (823.00, 823.02, 823.10 and 823.12) and the ORIF procedure code (79.36; n=156). Snow sport participants were defined as patients injured while skiing or snowboarding; patients were excluded for other injury causes (n=12). The primary exposure variable was time from injury to ORIF classified as immediate (≤24 hours post-injury) and delayed (>24 hours post-injury). Various time points defining immediate treatment intervals were found in the literature[17 20]; our cut-point was chosen a priori based on physician suggestion. At this hospital, there is no institutional standardized protocol for the timing at which ORIF is to be performed and instead is physician and circumstance dependent. External fixators were placed in the majority of the patients treated in the delayed group. However, some patients with delayed treatment may have been simply placed in a knee immobilizer or splint, without external fixation, and returned to the operating room (OR) for further definitive fixation or further debridement of fasciotomies before definitive fixation could be done. Patients with an unknown time between injury and ORIF were excluded from the analysis (n=2). We also excluded patients with a non-isolated TPF (n=9), defined as: (1) an Abbreviated Injury Scale greater than 1 for any region of the body other than the leg and/or (2) patients with pelvic or femur injuries. The patients with non-isolated fracture were excluded to maintain similar overall injury severities between groups and to exclude patients in which immediate ORIF may have been contraindicated or unfeasible due to other injuries requiring urgent attention. Finally, 14 patients were excluded after the imaging review for only having postoperative X-rays or CT scans (n=9) or having a tibial spine rather than plateau fracture (n=5).

The following in-hospital outcomes were compared between snow sport patients who underwent immediate versus delayed ORIF: incidence of compartment syndrome defined as a condition not present at admission in which there is documentation of tense muscular compartments through clinical assessment or direct measurement requiring fasciotomy, number of OR visits and procedures, number of fasciotomy procedures, infection, mortality, discharge disposition (home vs skilled nursing facilities), hospital LOS and admission to the intensive care unit (ICU). Patient demographic and clinical characteristics examined included: age, sex, race/ethnicity (white vs other), smoking status, presence of any comorbidities, Injury Severity Score (ISS; 4 vs ≥4), fracture type (open vs closed), time from injury to ORIF, high (Schatzker IV–VI) or low (Schatzker I–III) energy fracture and the AO/OTA fracture classification pattern.

The data were analyzed using SAS software (V.9.3). The Pearson or Fisher's exact $\chi^2$ test for categorical variables and the Wilcoxon two-sample test for continuous variables were used to examine differences between immediate and delayed ORIF in snow sport participants. These analyses were also performed in the subsets of patients with high-energy and low-energy fractures. Statistical significance was set at $p<0.05$.

## RESULTS

After applying the exclusion criteria, 119 patients sustained an isolated TPF while participating in snow sports (121 fractures). Immediate ORIF was performed in 93 (78%) patients. Thirty-six percent of the ORIFs were performed within the first 6 hours after injury, 35% between 6 and 12 hours, 7% between 12 and 24 hours, 22% 24–48 hours after injury and the remaining 9% performed more than 2 days after the injury was sustained (figure 2). ORIF occurred as far out as 19 days after injury.

Overall, the snow sport patients were predominantly white, male, non-smokers with few pre-existing comorbidities. The median age of the patients was 49 years, yet covered a wide range, from 19 to 70 years. Ten (8%) of the injured patients

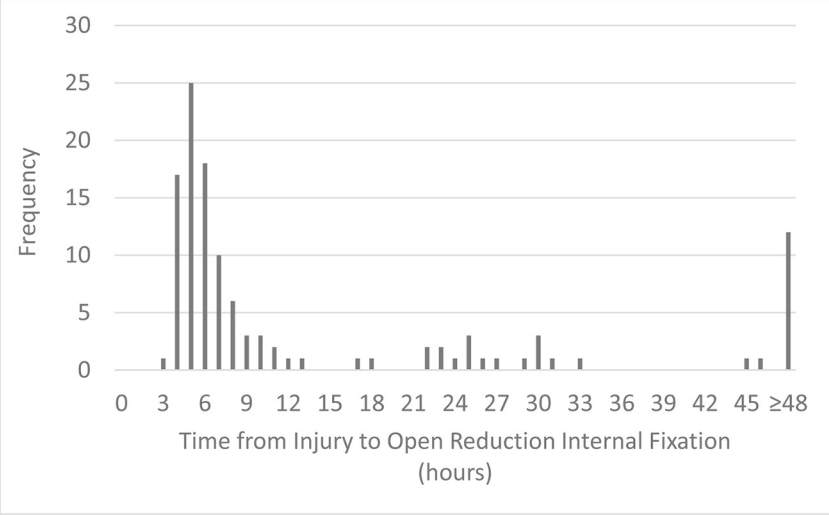


**Figure 2** Graph showing the timing from injury to open reduction internal fixation among injured skiers and snowboarders (n=119).

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 3 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.[17] 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.[20] 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.[17] 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

**Table 1** Characteristics and short-term outcomes of skiers and snowboarders with isolated tibial plateau fractures by immediate or delayed open reduction internal fixation (n=119)

| | Immediate (n=93) | Delayed (n=26) | p Value |
|---|---|---|---|
| Age, median (range), years | 49 (19–67) | 50 (22–70) | 0.88 |
| Male | 59 (63.4%) | 20 (76.9%) | 0.20 |
| White* | 75 (96.2%) | 22 (100%) | >0.99 |
| Smoker | 3 (3.2%) | 1 (3.9%) | >0.99 |
| No comorbidities | 77 (82.8%) | 20 (76.9%) | 0.57 |
| ISS=4 | 89 (95.7%) | 23 (88.5%) | 0.18 |
| Open fracture | 1 (1.1%) | 1 (3.9%) | 0.39 |
| Hospital arrival ≤180 min after injury† | 48 (53.3%) | 10 (40.0%) | 0.24 |
| Schatzker classification‡ | | | 0.16 |
| I | 2 (2.2%) | 2 (7.1%) | |
| II | 52 (55.9%) | 12 (42.9%) | |
| III | 3 (3.2%) | 2 (7.1%) | |
| IV | 3 (3.2%) | 4 (14.3%) | |
| V | 4 (4.3%) | 1 (3.6%) | |
| VI | 29 (31.2%) | 7 (25.0%) | |
| Schatzker classification‡ | | | 0.83 |
| Low energy (I–III) | 57 (61.3%) | 16 (57.1%) | |
| High energy (IV–VI) | 36 (38.7%) | 12 (42.9%) | |
| AO/OTA classification‡ | | | 0.40 |
| B1 | 2 (2.2%) | 2 (7.1%) | |
| B2 | 3 (3.2%) | 2 (7.1%) | |
| B3 | 55 (59.1%) | 16 (57.1%) | |
| C1 | 9 (9.7%) | 1 (3.6%) | |
| C2 | 5 (5.4%) | 0 (0%) | |
| C3 | 19 (20.4%) | 7 (25.0%) | |
| Time to ORIF, median (range), hours | 6.3 (4.0–23.7) | 45.9 (24.3–461.3) | **<0.001** |
| One trip to the operating room | 89 (95.7%) | 14 (53.9%) | **<0.001** |
| Compartment syndrome | 3 (3.2%) | 7 (26.9%) | **<0.001** |
| Fasciotomy§ | 6 (6.5%) | 8 (30.8%) | **0.002** |
| In-hospital infection | 0 (0%) | 0 (0%) | – |
| In-hospital mortality | 0 (0%) | 0 (0%) | – |
| Discharged home | 93 (100%) | 24 (92.3%) | **0.046** |
| LOS, median (range) | 3 (1–10) | 6.5 (1–34) | **<0.001** |

*Missing race for 19 patients.
†Missing hospital arrival time for four patients.
‡Two people had bilateral fractures (n=121).
§One person had more than one fasciotomy.
Data presented are n (%), unless otherwise specified; significant p values (p<0.05) are displayed in bold.
ISS, Injury Severity Score; LOS, length of stay; ORIF, open reduction internal fixation.

**Table 2** Mechanism of injury, fracture classification and time to ORIF in skiers compared with snowboarders

| | Skiers (n=109) | Snowboarders (n=10) | p Value |
|---|---|---|---|
| Mechanism of injury | | | **<0.001** |
| Collision | 18 (16.5%) | 5 (50.0%) | |
| Jump or terrain park | 1 (0.9%) | 4 (40.0%) | |
| Twisting or tumbling | 46 (42.2%) | 0 (0%) | |
| Fall, unknown mechanism | 44 (40.4%) | 1 (10.0%) | |
| Schatzker classification* | | | 0.75 |
| Low energy (I–III) | 67 (60.9%) | 6 (54.6%) | |
| High energy (IV–VI) | 43 (39.1%) | 5 (45.5%) | |
| AO/OTA classification* | | | 0.40 |
| B1 | 3 (2.7%) | 1 (9.1%) | |
| B2 | 4 (3.6%) | 1 (9.1%) | |
| B3 | 64 (58.2%) | 7 (63.6%) | |
| C1 | 9 (8.2%) | 1 (9.1%) | |
| C2 | 5 (4.6%) | 0 (0%) | |
| C3 | 25 (22.7%) | 1 (9.1%) | |
| Time to ORIF | | | 0.22 |
| Immediate | 87 (79.8%) | 6 (60.0%) | |
| Delayed | 22 (20.2%) | 4 (40.0%) | |

*Two people had bilateral fractures (n=121).
Significant p values (p<0.05) are displayed in bold.
ORIF, open reduction internal fixation.

noted that alpine ski injuries tend to be lower in energy, with minimal initial swelling, making same-day treatment a considerable option.[21] 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] Egol *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%)[5] 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 complications[12] and prophylactic antibiotics were not used for the entire control study period.[2] Though not specifically examining timing, 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=0.01); 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] Morris *et al* found a 14.2% rate of deep infection, despite staged fixation.[23] Our current study reported no infections; this is likely underreported as it only reflects in-hospital infection rates.

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; Rademakers *et al* noted excellent long-term (mean

**Table 3** Case series of patients with fasciotomies and compartment syndrome

| Patient | Immediate/delayed ORIF | Fasciotomy procedures (n) | Timing of fasciotomy procedure | Timing of compartment syndrome diagnosis |
|---|---|---|---|---|
| 1 | Delayed | 1 | Prior to ORIF | Prior to ORIF |
| 2 | Delayed | 1 | With ORIF | Same day as ORIF |
| 3 | Delayed | 1 | With ORIF | Same day as ORIF |
| 4 | Delayed | 1 | With ORIF | Fasciotomy for impending compartment syndrome |
| 5 | Delayed | 1 | Prior to ORIF | Prior to ORIF |
| 6 | Delayed | 1 | Prior to ORIF | Prior to ORIF |
| 7 | Delayed | 1 | Prior to ORIF | Prior to ORIF |
| 8 | Delayed | 1 | Prior to ORIF | Prior to ORIF |
| 9 | Immediate | 1 | With ORIF | Same day as ORIF |
| 10 | Immediate | 2 | First: with ORIF<br>Second: after ORIF | First fasciotomy for impending compartment syndrome; second for evolving compartment syndrome |
| 11 | Immediate | 1 | With ORIF | Same day as ORIF |
| 12 | Immediate | 1 | With ORIF | Same day as ORIF |
| 13 | Immediate | 1 | With ORIF | Fasciotomy for extent of injury and likelihood of compartment syndrome |
| 14 | Immediate | 1 | With ORIF | Fasciotomy for impending compartment syndrome |

ORIF, open reduction internal fixation.

14 years) outcomes with the ability to regain activity as prior to their injury for patients with TPF treated with ORIF.[1] Loibl *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).[24] Tang *et al* compared patients with Schatzker IV–VI TPFs who were surgically treated within 12 hours after surgery with patients who were first treated by traction or plaster fixation for 1–2 weeks. They found that, at 3 months postoperation, the delayed group had significantly better knee function as scored by the Hospital for Special Surgery scoring method but that this difference was not evident at the end of follow-up (mean 16.5 months).[17] Unfortunately, we do not have access to these data for our study population and are therefore 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 though 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 judged up front, using a consistent rubric, and long-term functional outcomes are examined.

A strength of this study is the specific focus on TPFs in skiers and snowboarders and the classification of these fractures to ensure the results persist even in patients sustaining high-energy fractures. The mechanism of injury for these patients was a fall (inside-out fracture mechanism, 81%) from snow sports in our study versus a motor vehicle collision (outside-in fracture

**Table 4** Characteristics and short-term outcomes of skiers and snowboarders with high-energy or low-energy isolated tibial plateau fractures by immediate or delayed open reduction internal fixation (n=119)

| | Patients with high-energy fracture (n=48) | | | Patients with low-energy fracture (n=71) | | |
|---|---|---|---|---|---|---|
| | Immediate (n=36) | Delayed (n=12) | p Value | Immediate (n=57) | Delayed (n=14) | p Value |
| Age, median (range), years | 44.5 (19–61) | 51.5 (22–63) | 0.23 | 51 (23–67) | 48.5 (25–70) | 0.24 |
| Male | 25 (69.4%) | 11 (91.7%) | 0.25 | 34 (59.7%) | 9 (64.3%) | >0.99 |
| No comorbidities | 30 (83.3%) | 8 (66.7%) | 0.24 | 47 (82.5%) | 12 (85.7%) | >0.99 |
| Hospital arrival ≤180 min after injury | 9 (25.0%) | 6 (50.0%) | 0.15 | 33 (61.1%) | 9 (69.2%) | 0.75 |
| One trip to the OR | 35 (97.2%) | 4 (33.3%) | **<0.001** | 54 (94.7%) | 10 (71.4%) | **0.02** |
| Compartment syndrome | 1 (2.8%) | 6 (50.0%) | **<0.001** | 2 (3.5%) | 1 (7.1%) | 0.49 |
| Fasciotomy* | 3 (8.3%) | 7 (58.3%) | **<0.001** | 3 (5.3%) | 1 (7.1%) | >0.99 |
| Discharged home | 36 (100%) | 11 (91.7%) | 0.25 | 57 (100%) | 13 (92.9%) | 0.20 |
| LOS, median (range) | 3 (1–10) | 8 (4–20) | **<0.001** | 2 (1–7) | 3.5 (1–34) | **0.006** |

*One patient had more than one fasciotomy.
Data presented are n (%), unless otherwise specified; significant p values (p<0.05) are displayed in bold.
LOS, length of stay; OR, operating room.

mechanism, 54%–93%[1 4–6]) 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.

**Acknowledgements** The authors wish to thank Paula Hanson and Shelly Almroth for their assistance in obtaining the registry data. The authors would also like to thank Paul Abbott, MD for reviewing imaging and classifying the fractures per theSchatzker and AO/OTA classification system.

**Contributors** PCJ 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. BJB, DSS and CWM provided critical manuscript revisions. DBO participated in the study design and provided critical manuscript revisions. All authors read and approved the final manuscript.

**Competing interests** None declared.

**Ethics approval** Catholic Health Initiatives Institute for Research and Innovation Institutional Review Board.

**Provenance and peer review** Not commissioned; externally peer reviewed.



## REFERENCES

1 Rademakers MV, Kerkhoffs GM, Sierevelt IN, Raaymakers EL, Marti RK. Operative treatment of 109 tibial plateau fractures: five- to 27-year follow-up results. *J Orthop Trauma* 2007;21:5–10.
2 Moore TM, Patzakis MJ, Harvey JP. Tibial plateau fractures: definition, demographics, treatment rationale, and long-term results of closed traction management or operative reduction. *J Orthop Trauma* 1987;1:97–119.
3 Kennedy JC, Bailey WH. Experimental tibial-plateau fractures. Studies of the mechanism and a classification. *J Bone Joint Surg Am* 1968;50:1522–34.
4 Benirschke SK, Agnew SG, Mayo KA, Santoro VM, Henley MB. Immediate internal fixation of open, complex tibial plateau fractures: treatment by a standard protocol. *J Orthop Trauma* 1992;6:78–86.
5 Egol KA, Tejwani NC, Capla EL, Wolinsky PL, Koval KJ. Staged management of high-energy proximal tibia fractures (OTA types 41): the results of a prospective, standardized protocol. *J Orthop Trauma* 2005;19:448–55. discussion 456.
6 Manidakis N, Dosani A, Dimitriou R, Stengel D, Matthews S, Giannoudis P. Tibial plateau fractures: functional outcome and incidence of osteoarthritis in 125 cases. *Int Orthop* 2010;34:565–70.
7 Blokker CP, Rorabeck CH, Bourne RB. Tibial plateau fractures. An analysis of the results of treatment in 60 patients. *Clin Orthop Relat Res* 1984;182:193–9.
8 Hak DJ, Lee M, Gotham DR. Influence of prior fasciotomy on infection after open reduction and internal fixation of tibial plateau fractures. *J Trauma* 2010;69:886–8.
9 Ebraheim NA, Sabry FF, Haman SP. Open reduction and internal fixation of 117 tibial plateau fractures. *Orthopedics* 2004;27:1281–7.
10 Stannard JP, Lopez R, Volgas D. Soft tissue injury of the knee after tibial plateau fractures. *J Knee Surg* 2010;23:187–92.
11 Urruela AM, Davidovitch R, Karia R, Khurana S, Egol KA. Results following operative treatment of tibial plateau fractures. *J Knee Surg* 2013;26:161–6.
12 Young MJ, Barrack RL. Complications of internal fixation of tibial plateau fractures. *Orthop Rev* 1994;23:149–54.
13 Edlund G, Gedda S, Hemborg A. Knee injuries in skiing. A prospective study from northern Sweden. *Am J Sports Med* 1980;8:411–4.
14 Stenroos A, Pakarinen H, Jalkanen J, Mälkiä T, Handolin L. Tibial fractures in alpine skiing and snowboarding in finland: a retrospective study on fracture types and injury mechanisms in 363 patients. *Scand J Surg* 2016;105:191–6.
15 Berkson EM, Virkus WW. High-energy tibial plateau fractures. *J Am Acad Orthop Surg* 2006;14:20–31.
16 Dirschl DR, Del Gaizo D. Staged management of tibial plateau fractures. *Am J Orthop* 2007;36:12–17.
17 Tang X, Liu L, Tu CQ, Yang TF, Wang GL, Fang Y, Li J, Li Q, Pei FX. Timing of internal fixation and effect on Schatzker IV–VI tibial plateau fractures. *Chin J Traumatol* 2012;15:81–5.
18 Schatzker J, McBroom R, Bruce D. The tibial plateau fracture. The Toronto experience 1968–1975. *Clin Orthop* 1979;138:94–104.
19 Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, Prokuski L, Sirkin MS, Ziran B, Henley B *et al*. Fracture and dislocation classification compendium—2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma* 2007;21:S1–133.
20 Xu YQ, Li Q, Shen TG, Su PH, Zhu YZ. An efficacy analysis of surgical timing and procedures for high-energy complex tibial plateau fractures. *Orthop Surg* 2013;5:188–95.
21 Harris NL, Purnell ML, Pevny T, Larson AI , *et al*. Arthroscopic management of tibial plateau fractures. *Techniques in Knee Surgery* 2007;6:9–16.
22 Metcalfe D, Hickson CJ, McKee L, Griffin XL. External versus internal fixation for bicondylar tibial plateau fractures: systematic review and meta-analysis. *J Orthop Traumatol* 2015;16:275–85.
23 Morris BJ, Unger RZ, Archer KR, Mathis SL, Perdue AM, Obremskey WT. Risk factors of infection after ORIF of bicondylar tibial plateau fractures. *J Orthop Trauma* 2013;27:e196–e200.
24 Loibl M, Bäumlein M, Massen F, Gueorguiev B, Glaab R, Perren T, Rillmann P, Ryf C, Naal FD. Sports activity after surgical treatment of intra-articular tibial plateau fractures in skiers. *Am J Sports Med* 2013;41:1340–7.