Arthrofibrosis of the knee following a fracture of the tibial plateau

J. M. Haller, D. C. Holt, M. L. McFadden, T. F. Higgins, E. N. Kubiak

From University of Utah School of Medicine, Department of Orthopaedics, Utah, United States

The aim of this study was to report the incidence of arthrofibrosis of the knee and identify risk factors for its development following a fracture of the tibial plateau. We carried out a retrospective review of 186 patients (114 male, 72 female) with a fracture of the tibial plateau who underwent open reduction and internal fixation. Their mean age was 46.4 years (19 to 83) and the mean follow-up was 16.0 months (6 to 80).

A total of 27 patients (14.5%) developed arthrofibrosis requiring a further intervention. Using multivariate regression analysis, the use of a provisional external fixator (odds ratio [OR] 4.63, 95% confidence interval [CI] 1.26 to 17.7, p = 0.021) was significantly associated with the development of arthrofibrosis. Similarly, the use of a continuous passive movement (CPM) machine was associated with significantly less development of arthrofibrosis (OR = 0.32, 95% CI 0.11 to 0.83, p = 0.024). The effect of time in an external fixator was found to be significant, with each extra day of external fixation increasing the odds of requiring manipulation under anaesthesia (MUA) or quadricepsplasty by 10% (OR = 1.10, p = 0.030). High-energy fracture, surgical approach, infection and use of tobacco were not associated with the development of arthrofibrosis. Patients with a successful MUA had significantly less time to MUA (mean 2.9 months; SD 1.25) than those with an unsuccessful MUA (mean 4.86 months; SD 2.61, p = 0.014). For those with limited movement, therefore, performing an MUA within three months of the injury may result in a better range of movement.

Based on our results, CPM following operative fixation for a fracture of the tibial plateau may reduce the risk of the development of arthrofibrosis, particularly in patients who also undergo prolonged provisional external fixation.

Cite this article: Bone Joint J 2015;97-B:109–14.

In general, an arc of movement of the knee from 0° to 125° is adequate for most patients for activities of daily living. Gait analysis has shown that patients require 67° of flexion during the swing phase of gait and > 90° to descend stairs and rise from a chair. A loss of extension of 5° can significantly increase the energy expenditure of the quadriceps muscle and produce a limp.

Arthrofibrosis of the knee after total knee arthroplasty (TKA) and ligament reconstruction has been studied extensively. The incidence of arthrofibrosis after TKA is reported to be up to 5.3% in large series. Risk factors for arthrofibrosis after TKA include a limited pre-operative range of movement (ROM), previous surgery, poor compliance and post-operative infection. In more recent studies, the incidence of arthrofibrosis following ligament reconstruction is reported to be between 0% and 4%. Risk factors in this setting include early surgery after injury, prolonged immobilisation, delayed rehabilitation and the severity of the injury. Treatment options for patients with arthrofibrosis of the knee include continued physiotherapy, manipulation under anaesthesia (MUA), arthroscopic release of adhesions and quadricepsplasty.

The reported incidence of arthrofibrosis following a fracture of the tibial plateau is up to 7% following high-energy fractures. In these studies, arthrofibrosis and an unacceptable ROM have been variously defined. The purpose of this study was to determine the incidence and risk factors for the development of arthrofibrosis following a fracture of the tibial plateau. To our knowledge this has not previously been reported. Our hypothesis was that patients with a high-energy fracture of the tibial plateau and those who underwent spanning external fixation were at an increased risk of developing arthrofibrosis, and that those who used a continuous passive movement (CPM) machine post-operatively were at a reduced risk.
Patients and Methods

After receiving institutional review board approval, we retrospectively reviewed the medical records of patients > 18 years of age who presented to our level 1 trauma centre with a fracture of the tibial plateau between 1 January 2005 and 30 June 2012. During this period, 404 fractures of the tibial plateau were treated operatively and met the inclusion criteria. A total of 218 patients with follow up of < six months were excluded; the remaining 186 formed our study cohort. The mean age of the patients was 46.4 years (19 to 83) and 114 (61%) were men. The mean follow-up was 16.0 months (6 to 80). In all, 38 patients (20.4%) were smokers, and 16 (8.6%) had diabetes mellitus (Table I). A provisional external fixator was used in 98 patients (53%).

Our indications for spanning external fixation included those with fracture patterns that were axially unstable, subluxation of the knee, injuries with significant soft-tissue swelling, symptoms of compartment syndrome requiring fasciotomy, injuries with associated vascular compromise, and/or patients too medically unstable for open reduction and internal fixation (ORIF). Spanning frames consisted of two 5 mm half-pins in the distal femoral diaphysis and two 5 mm half-pins in the anteromedial aspect of the tibial diaphysis. In 78 patients (41.9%) a dual approach was used, in 80 (43%) a lateral approach and in 28 (15.1%) a medial approach. The overall rate of deep infection was 8.6% (16 patients).

Fractures were classified using the Orthopaedic Trauma Association and Schatzker classification systems.

<table>
<thead>
<tr>
<th>Table I. Demographics of the patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>No arthrofibrosis (n = 159)</strong></td>
</tr>
<tr>
<td><strong>Arthrofibrosis (n = 27)</strong></td>
</tr>
<tr>
<td><strong>p-value</strong></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Male gender (%)</td>
</tr>
<tr>
<td>Diabetes (%)</td>
</tr>
<tr>
<td>Tobacco use (%)</td>
</tr>
<tr>
<td>Injury severity score*</td>
</tr>
</tbody>
</table>

**Mechanism**

| MVC | 29 | 3 |
| MCC | 22 | 6 |
| Fall | 45 | 7 |
| Skiing | 22 | 3 |
| GLF | 18 | 1 |

**Pedestrian vs automobile**

| 8 | 1 |

| ATV/snowmobile | 5 | 2 |
| Other (crush etc.) | 10 | 4 |

Our indications for spanning external fixation included those with fracture patterns that were axially unstable, subluxation of the knee, injuries with significant soft-tissue swelling, symptoms of compartment syndrome requiring fasciotomy, injuries with associated vascular compromise, and/or patients too medically unstable for open reduction and internal fixation (ORIF). Spanning frames consisted of two 5 mm half-pins in the distal femoral diaphysis and two 5 mm half-pins in the anteromedial aspect of the tibial diaphysis. In 78 patients (41.9%) a dual approach was used, in 80 (43%) a lateral approach and in 28 (15.1%) a medial approach. The overall rate of deep infection was 8.6% (16 patients).

Fractures were classified using the Orthopaedic Trauma Association and Schatzker classification systems.

<table>
<thead>
<tr>
<th>Table II. Comparison of the characteristics of patients who developed arthrofibrosis and patients who did not</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No arthrofibrosis (n = 159)</strong></td>
</tr>
<tr>
<td><strong>Approach</strong></td>
</tr>
<tr>
<td>Dual</td>
</tr>
<tr>
<td>Medial</td>
</tr>
<tr>
<td>High-energy fracture</td>
</tr>
<tr>
<td>Low-energy fracture</td>
</tr>
<tr>
<td>External fixation</td>
</tr>
<tr>
<td>Time in external fixator (mean, SD) (days) (days)</td>
</tr>
<tr>
<td>Continuous passive movement</td>
</tr>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Open</td>
</tr>
<tr>
<td>Tobacco</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Tobacco</td>
</tr>
<tr>
<td>No</td>
</tr>
</tbody>
</table>

* Student’s t-test
† Chi-squared
‡ Fisher’s exact test

GLF, ground level fall; ATV, all terrain vehicle; MVC, motor vehicle collision; MCC, motorcycle collision.
Non-osteopenic Schatzker IV, V and VI fractures were considered high-energy injuries. Schatzker I, II and III fractures were considered low-energy. Accordingly, 130 patients (70%) sustained a high-energy fracture and 56 (30%) sustained a low-energy fracture (Table II). Open injuries were classified according to the Gustilo–Anderson classification. There were 14 patients (7.5%) with an open fracture: five grade II, four grade IIIa and four grade IIIb. Injury severity scores (ISS) were recorded for all patients.

The medical records were reviewed to identify which patients received treatment with a CPM machine and the outcome data. Physiotherapy notes were reviewed to determine CPM machine usage while in hospital, and discharge instructions, discharge summaries and home therapy notes were reviewed to determine CPM machine usage at home. Indications for CPM included the ability of the patient to tolerate it, and the attending surgeon’s discretion, based on adequate bone quality, fixation and surrounding soft-tissue injury. Patients continued to use the CPM machine as much as tolerated for up to two weeks after injury. Regardless of whether a patient received CPM, he/she started passive knee exercises with physiotherapy on the first post-operative day. In all, 78 patients (41.9%) used a CPM machine in addition to physiotherapy. Of these 78, 59 (75.6%) had a high-energy fracture. Following discharge, patients worked on passive ROM for the first six weeks, followed by active ROM and gentle strengthening from six to 12 weeks post-operatively. Patients were allowed to initiate weight-bearing between ten and 12 weeks post-operatively.

Arthrofibrosis was defined as a requirement for either MUA or an invasive surgical procedure to restore movement. The attending surgeon measured the ROM of the knee using a goniometer. The criterion for an MUA was failure of progression with ROM with the assistance of physiotherapy within six months of injury; inadequate movement (< 90° flexion or > 10° flexion contracture) at six months; or inadequate movement for activities of daily living, as determined by the patient. Those with compartment syndrome underwent a four-compartment fasciotomy followed by serial debridement until definitive closure could be achieved. Those with post-operative infection underwent serial irrigation and debridement until a clean and perfused wound bed was obtained. These patients were treated with antibiotics, either parenterally or intravenously, for a minimum of six weeks. Collected peri-operative data included post-operative infection, use of an external fixator, and surgical approach.

Statistical analysis. Pearson’s chi-squared test and Fisher’s exact test were used for the categorical variables between patients with and without arthrofibrosis, including gender, tobacco use and compartment syndrome. The Student’s t-test was used for continuous variables, including age, follow-up, ISS etc. A logistic multivariate regression model was used to predict the development of arthrofibrosis based on the following variables: high-energy fracture; CPM use; the use of external fixation; use of a lateral, medial or dual surgical approach; tobacco use and the presence of infection.

In order to test for the association of time in an external fixator with the requirement for MUA, we used a logistic regression model controlling for the covariates listed above. In order to isolate the effect of time, the analysis was limited to those who had external fixation. Analyses were conducted using Proc Logistic SAS statistical software, version 9.3 (SAS Institute, Cary, North Carolina), and p < 0.05 was used to define statistical significance.

Results
A total of 27 patients (14.5%) developed arthrofibrosis requiring a secondary procedure (26 MUAs and one quadricepsplasty). There was no statistical difference in age, gender, the presence of diabetes mellitus, tobacco use or ISS between those who developed arthrofibrosis and those who did not (Table I). The mean pre-operative ROM was 1° (0° to 10°) to 74° (10° to 118°). The mean post-operative ROM was 1° (0° to 5°) to 129° (110° to 147°). The mean time between fixation and the secondary procedure was 91 days (28 to 153). The mean final ROM was 2° (0° to 25°) to 120° (90° to 147°) at a mean of eight months (3 to 24) after the procedure to improve the ROM. Assuming functional ROM to be a flexion contracture of < 5° and flexion > 125°, at the final follow-up, 20 patients (74%) had a functional ROM after MUA. The patients with successful MUA had a significantly shorter interval to MUA (mean 2.9 months; SD 1.25) than those with an unsuccessful MUA (mean 4.86 months; SD 2.61; p = 0.014, logistic multivariate regression).
Of the 98 patients who were treated with external fixation, 23 (23.5%) developed arthrofibrosis requiring intervention. After controlling for surgical approach, high-energy fracture, CPM, tobacco use and infection, the use of a fixator (OR = 4.63, 95% CI 1.26 to 17.7, p = 0.021) was significantly associated with the development of arthrofibrosis (Table II). The mean length of time in external fixation for those who developed arthrofibrosis was 12.1 days (4 to 30) and for those who did not was 8.7 days (1 to 33). The effect of time was found to be significant, with an OR of 1.10 (95% CI 1.01 to 1.20, p = 0.03). For each extra day of external fixation, the risk of developing arthrofibrosis increased by 10%.

Of the 130 patients with a high-energy fracture of the tibial plateau, 24 (18.5%) developed arthrofibrosis. When high-energy fracture was considered in the same model as external fixation, its effect was not significant (p = 0.90, logistic multivariate regression). However, high-energy fracture and external fixation were highly associated, with 91 of 98 patients (92.9%) who were treated with external fixation also having a high-energy fracture (1 degree of freedom = 51.9, p < 0.001, chi-squared test). Using the same model but excluding external fixation, the association between high-energy injury and arthrofibrosis was more marked but not significant (OR = 2.44, 95% CI 0.47 to 12.7, p = 0.29).

Two patients with an open fracture and five with post-operative infection developed arthrofibrosis. Surgical approach, post-operative infection and tobacco use were not associated with an increased development of arthrofibrosis (Table III). Only six patients who used a CPM machine developed arthrofibrosis. Using multivariate analysis, CPM use was associated with significantly less development of arthrofibrosis (OR = 0.30, 95% CI 0.11 to 0.83, p = 0.021). When only high-energy fractures were included, the use of a CPM machine continued to be associated with significantly less development of arthrofibrosis (OR = 0.3, 95% CI 0.09 to 0.73, p = 0.011). Similarly, when only patients who were treated with external fixation were included, CPM use continued to be associated with significantly less development of arthrofibrosis (OR = 0.28, 95% CI 0.092 to 0.86, p = 0.026).

Discussion
Fractures of the tibial plateau are severe injuries that can be associated with significant morbidity. Arthrofibrosis of the knee should remain a concern for the treating orthopaedic surgeon. Ours is the first study to identify risk factors for the development of post-traumatic arthrofibrosis. In agreement with our hypothesis, we found that the use of an external fixator was associated with a significantly increased risk of developing arthrofibrosis, and the use of a CPM machine significantly reduced this risk. Despite the coincidence between high-energy fracture and external fixation, we also found that a high-energy fracture was not associated with developing arthrofibrosis.

Although the exact aetiology is unknown, there are studies suggesting that genetics and the over-expression of transforming growth factor-β (TGF-β) may play a role in the development of arthrofibrosis.20,21 Platelet-derived growth factor and transforming growth-factor-β1 (TGF-β1) are inflammatory cytokines that promote fibroblast and extracellular matrix protein proliferation, protease inhibition and collagen production. These cytokines are present after injury, and an increase in the local concentration can trigger feedback inhibition of the TGF-β autoregulatory mechanism.21 Additionally, a genetic predisposition to an overactive inflammatory system can lead to enhanced scar formation and tissue shrinkage.22 Our finding that high-energy fractures were not associated with an increased risk of developing arthrofibrosis is contrary to the known relationship between increased inflammatory response and arthrofibrosis. The lack of association may be due to our use of the Schatzker classification17 to define a high-energy fracture. Whether a patient was treated by external fixation may be a better indicator of the energy of the fracture than the Schatzker classification.

There are few studies that have reported the incidence of arthrofibrosis requiring intervention after a fracture of the tibial plateau. In a prospective randomised study comparing ring fixators with ORIF for 83 high-energy plateau injuries, the Canadian Orthopaedic Trauma Society found that 6.0% of patients with a fracture of the tibial plateau required a manipulation under anaesthesia. Although there was a similar incidence between the two treatment groups (three patients in the external fixation group and two in the ORIF group), the ORIF group were not also treated by external fixation.13 In a study of 57 high-energy tibial plateau injuries treated with staged management using a provisional external fixator, Egol et al14 reported that only two patients (4%) had a ROM of the knee < 90°. In a series of 83 patients, Barei et al13 reported that six patients (7.2%) with a high-energy plateau fracture required additional surgery or a manipulation for limited movement of the knee. A temporary external fixator was used in 50% of these patients. Our rate of the development of arthrofibrosis of 14.5% is much higher than in these previous studies, which included only high-energy plateau fractures. Selecting only high-energy injuries, our arthrofibrosis rate of 18.5% is even higher. The studies by Barei et al13 and Egol et al14 had similar or higher rates of provisional external fixator use, which we identified as a risk factor for the development of arthrofibrosis. Barei et al13 reported routinely using CPM post-operatively, which we identified as reducing the risk of arthrofibrosis. This may account for the lower rate of arthrofibrosis in that study.

Several prospective randomised studies have evaluated the use of CPM following TKA, with conflicting results. Some studies have shown better ROM of the knee following use of CPM,23-26 but the studies used different rehabilitation protocols. A recent prospective randomised trial comparing outcomes in patients with and without CPM
following TKA using the same post-operative physiotherapy programme showed no difference in ROM or incidence of arthrofibrosis. A recent Cochrane Review found that CPM use after TKA was associated with a slight improvement in ROM and may reduce the incidence of MUA for stiffness. Our study is the first to identify CPM as a possible way of reducing the risk of arthrofibrosis after fractures of the tibial plateau. There are no prospective studies evaluating CPM use for plateau fractures.

Prolonged immobilisation and delayed rehabilitation have been identified as risk factors for the development of arthrofibrosis. Movement following an injury may reduce the formation of adhesions and potentially reduce the risk of stiffness. Additionally, early movement following an injury may reduce the formation of infection rates dramatically. A recent study found that CPM use after TKA was associated with a slight improvement in ROM and may reduce the incidence of MUA for stiffness. Our study is the first to identify CPM as a possible way of reducing the risk of arthrofibrosis after fractures of the tibial plateau. There are no prospective studies evaluating CPM use for plateau fractures.

This study has several limitations, including its retrospective design and the inclusion of many surgeons treating these injuries. Defining arthrofibrosis as any patient who underwent manipulation may be criticised as being subjective and dependent on the surgeon. Our primary endpoint, the decision to proceed with an intervention to increase movement, is essentially an elective procedure selected by the patient in conjunction with the surgeon. This is relevant in clinical practice, because these patients require a further anaesthetic to regain motion. Also, there may be a selection bias towards CPM for less severe injuries. However, 75% of the patients who received CPM had a high-energy injury. Another limitation is the minimum follow-up of only six months. We chose this time because it is our practice to address limitation of movement before the six-month follow-up visit. Additionally, we did not report the ROM of the patients who did not undergo an MUA. Finally, we did not include any outcome data, as these were not available for analysis.

In conclusion, we have shown that the incidence of arthrofibrosis following a fracture of the tibial plateau is higher than previously reported. We have identified that the use of an external fixator is associated with an increased risk of developing arthrofibrosis. High-energy fracture, surgical approach, tobacco use and infection were not associated with an increased rate of arthrofibrosis. The amount of time in an external fixator was associated with the development of arthrofibrosis. The use of a CPM machine was found to reduce the risk of developing arthrofibrosis.

Finally, for patients with limited movement, performing an MUA within three months of injury may result in a better final ROM. Based on these findings, we recommend consideration of CPM for patients undergoing staged management of a fracture of the tibial plateau.

J. M. Haller: Study design, Data acquisition and analysis, Manuscript preparation, Manuscript review.
D. C. Holt: Study design, Data acquisition and analysis, Manuscript preparation, Manuscript review.
M. L. McFadden: Statistical analysis, Manuscript preparation, Manuscript review.
E. N. Kubiak: Study design, Data analysis, Manuscript preparation, Manuscript review.

This investigation was supported by the Design and Biosciences Center, with funding in part from the National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health, through Grant UL1TR000105.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

This article was primarily edited by G. Scott and first proof edited by J. Scott.

References


VOL. 97-B, No. 1, JANUARY 2015


