We assessed the functional outcome following fracture of the tibial plateau in 63 consecutive patients. Fifty-one patients were treated by internal fixation, five by combined internal and external fixation and seven non-operatively. Measurements of joint movement and muscle function were made using a muscle dynamometer at three, six and 12 months following injury. Thirteen patients (21%) had a residual flexion contracture at one year. Only nine (14%) patients achieved normal quadriceps muscle strength at 12 months, while 19 (30%) achieved normal hamstring muscle strength. Recovery was significantly slower in patients older than 40 years of age. We conclude that there is significant impairment of movement and muscle function after fracture of the tibial plateau and that the majority of patients have not fully recovered one year after injury.

Loss of movement and reduced muscle function affects recovery after intra-articular fractures. Movement has been shown to encourage the healing of articular cartilage in an animal model. Fractures of the tibial plateau are relatively common and often occur in an active population. Weakness of the muscles controlling the knee joint, especially the quadriceps, is a common complication. Functional recovery following ligamentous injury to the knee has been well documented. However, there is only one published retrospective study evaluating functional recovery after fracture of the tibial plateau. The aim of this study was to evaluate the recovery of knee movement, and the strength of the quadriceps and hamstring muscles prospectively, in the first year after fracture of the tibial plateau.

Patients and Methods

Between May 1996 and December 2001, all patients who were admitted with an isolated fracture of the tibial plateau were considered for inclusion in the study. Exclusion criteria included a fracture elsewhere in the limb, a contralateral lower limb fracture, and multiple trauma.

We entered 63 patients into the study, with a mean age of 45 years (16 to 81). Details of the injuries are shown in Table I. Shatzker's classification system was used. Seven fractures were treated non-operatively, 51 were treated by internal fixation and the five type VI fractures were treated by minimal internal fixation augmented with external fixation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>34</td>
</tr>
<tr>
<td>Women</td>
<td>29</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td></td>
</tr>
<tr>
<td>Mean (range)</td>
<td></td>
</tr>
<tr>
<td>&lt; 40</td>
<td>30</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>33</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
</tr>
<tr>
<td>Low energy</td>
<td>34</td>
</tr>
<tr>
<td>Simple fall</td>
<td>15</td>
</tr>
<tr>
<td>Sport</td>
<td>12</td>
</tr>
<tr>
<td>Direct blow</td>
<td>7</td>
</tr>
<tr>
<td>High energy</td>
<td>29</td>
</tr>
<tr>
<td>RTA* motorcycle</td>
<td>11</td>
</tr>
<tr>
<td>RTA pedestrian</td>
<td>10</td>
</tr>
<tr>
<td>RTA car occupant</td>
<td>4</td>
</tr>
<tr>
<td>Fall from height</td>
<td>4</td>
</tr>
<tr>
<td>Shatzker grade</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>II</td>
<td>23</td>
</tr>
<tr>
<td>III</td>
<td>12</td>
</tr>
<tr>
<td>IV</td>
<td>11</td>
</tr>
<tr>
<td>V</td>
<td>3</td>
</tr>
<tr>
<td>VI</td>
<td>5</td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
</tr>
<tr>
<td>Non-operative</td>
<td>7</td>
</tr>
<tr>
<td>ORIF†</td>
<td>51</td>
</tr>
<tr>
<td>ORIF + external fixation</td>
<td>5</td>
</tr>
</tbody>
</table>

* RTA, road traffic accident
† ORIF, open reduction and internal fixation

The patients who did not have external fixation were mobilised in a hinged knee brace allowing full extension and 90° of flexion for the first six weeks. They were advised to remain non-weight-bearing for four weeks,
Fig. 1
Peak torque values for quadriceps (bars indicate 95% confidence intervals).

Fig. 2
Peak torque values for hamstrings (bars indicate 95% confidence intervals).

Fig. 3
Percentage muscle recovery after fracture of the tibial plateau (bars indicate 95% confidence intervals).

Fig. 4
Percentage muscle recovery for patients treated by open reduction and internal fixation (bars indicate 95% confidence intervals).

Fig. 5
Percentage quadriceps recovery by age (bars indicate 95% confidence intervals).

Fig. 6
Percentage recovery by Shatzker grade (bars indicate 95% confidence intervals).
Results
Fifty-two patients (82%) had a 100° knee flexion and 39 (62%) had an extension deficit of < 5° at three months. By this time, 52 patients (82%) had > 100° knee flexion and 39 patients (62%) had an extension deficit of < 5° at three months. By three months, six months and 12 months after the injury.

Discussion
The findings of this study indicate that quadriceps function is impaired for a considerable period following a fracture of the tibial plateau. We found that only 14% of patients achieved normal quadriceps muscle strength at one year, while only 30% had restoration of normal hamstring muscle strength at this time. Quadriceps strength recovered more slowly than hamstring strength throughout the period of follow-up. Older age was associated with a significantly slower return of quadriceps strength. These are similar findings to those previously reported for diaphyseal fractures of the tibia. None of the other demographic or injury factors affected the recovery of muscle strength in this study. We also found that more than 20% of patients had significant residual knee stiffness one year after injury.

To our knowledge, this is the first prospective study to use an objective outcome measure to assess function after fractures of the tibial plateau. The Biodex dynamometer has been shown to be a reliable device for assessing muscle function and isokinetic dynamometry has been validated in the literature. We have previously reported the use of this technique in other types of injury.

A limitation of this study is the small numbers in some of the demographic subgroups which increases the possibility of a type II error with some true differences not being detected. In Figure 6, those patients with more severe fracture patterns were weaker at their initial assessment than achieved the same level by one year. The initial difference was not statistically significant, possibly because there were very few of these more complex fractures. However, it is possible that there may be a difference in the rate of recovery of muscle function following the more severe fracture patterns. Another possible criticism is the use of the uninjured limb as the control. It has been reported that there are few differences between the right and left limb in terms of muscle strength, even in those whose sport

and partial weight-bearing for a further two. Progression to full-weight-bearing began at six weeks when the brace was removed. All had a standard physiotherapy regime, which was continued for 12 weeks after injury. None was lost to follow-up.

Any complications were recorded at each visit. The range of movement in the injured and uninjured limbs was measured using a goniometer. Muscle function was assessed using a Biodex System 2 dynamometer (Biodex Medical Systems Inc., Shirley, New York). This measured isokinetic peak torque (PT), total work (TW) and average power (AP) for knee flexion and extension. Each evaluation consisted of an active warm-up period followed by 5, 10 and 15 repetitions respectively carried out at three different speeds 90, 180 and 270° per second. The values for the uninjured limb were measured for comparison. A research physiotherapist (EMW) measured the range of movement and carried out all the isokinetic tests. The measurements were taken at three months, six months and 12 months after the injury.

For the purposes of this study only peak torque at the medium speed of 180° per second is used since it has been shown in a previous study that there is a very strong correlation between all three parameters (PT, TW and AP) and at all dynamic speeds. This correlation has been found by other authors.

Statistical analysis was carried out using SPSS software (SPSS Inc, Chicago, Illinois). A paired-sample t-test was used for comparing parameters at different time intervals and a one-sample t-test was used for assessing differences between groups at one time point. Values for p < 0.05 were regarded as significant. The results were presented graphically with the corresponding 95% confidence intervals (CI).

Results
Fifty-two patients (82%) had a 100° knee flexion and 39 (62%) had an extension deficit of < 5° at three months. By one year, 13 (21%) patients still had an extension deficit ≥ 5°.

The values of PT for the quadriceps and hamstring muscles at each time point are shown in Figures 1 and 2. There was no significant change in the values for the uninjured limb over the period of study. We used the uninjured limb as the control, with the value achieved in the uninjured limb expressed as a percentage of that in the uninjured limb. By this method, the level of recovery in the injured limb was generated at each time point.

Figure 3 shows the percentage recovery for both muscle groups. Quadriceps recovery lags behind the hamstrings at all time points. The mean extension torque is only 77% of the uninjured side by 12 months compared with 90% for flexion. These differences between quadriceps and hamstrings were significant at both six months (p < 0.01) and one year (p < 0.001). Only nine (14%) patients achieved normal quadriceps muscle strength at 12 months while 19 (30%) achieved normal hamstring muscle strength by this time. Figure 4 shows the percentage recovery for the 51 patients who were treated by open reduction and internal fixation and is similar to that for the whole group (Fig. 3).

All subsequent analyses were for quadriceps recovery only. Patients under 40 years of age recovered faster than those older than 40 years of age at each time point (Fig. 5). One year after the injury patients under 40 had regained 85% of their quadriceps strength, the older group had regained 74% (p < 0.05). Patients with more complex fracture configurations (Schatzker types 4 to 6) had worse quadriceps recovery initially, but there was no difference at one year (Fig. 6). Gender and mechanism of injury had no influence on the level or speed of recovery.

There were three superficial wound infections, which responded to antibiotic therapy. One deep infection required removal of the metalwork. There were three compartment syndromes which were all recognised early and treated with fasciotomy. No patient required muscle debridement. Two patients developed deep venous thrombosis and one patient had a common peroneal nerve palsy.
involves the predominant use of one lower limb for kick-
ing.\textsuperscript{13} We believe that the relative strength of the injured limb at any given time after trauma is of importance to our patients, because this is how they would naturally assess their own recovery. No other measures of outcome such as functional scoring systems were used in this study. How-
ever, we believe isokinetic measurements are a useful research tool. The results give clinicians objective data of what happens to the function of muscles following injury, enabling them to advise patients accordingly.

There are few reports of objective functional outcomes after fractures of the lower limb in the literature. Most are retrospective and the findings are, therefore, not directly comparable with our own.\textsuperscript{16-19} We can only find one other study looking at muscle strength after fracture of the tibial plateau.\textsuperscript{8} In this study, the mean torque deficit in the quadriceps of the injured limb was 16\% at 180˚, while the corresponding deficit in the hamstrings was 8\%. While these results are similar to our own, this was a retrospective study and the functional outcome assessments were made at a mean of seven years after injury, which may limit the clinical relevance of the findings.

In conclusion, patients with a fracture of the tibial plateau can be advised that there is a 20\% risk of residual stiffness at one year and, in the majority of cases, recovery of muscle function will still be incomplete at this stage. Quadriceps recovery was only complete in 14\% of cases at one year. Older patients can expect a slower recovery.

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References
1. Hurley MV. The effects of joint damage on muscle function, proprioception and reha-
3. Keating JF, Hajducka CL, Harper J. Minimal internal fixation and calcium-phos-
4. Rutherford OM, Jones DA, Round JM. Long-lasting unilateral muscle wasting and
5. Young A, Hughes I, Round JM, Edwards RH. The effect of knee injury on the num-
8. Honkonen SE, Kannus P, Natri A, Latvala K, Jarvinen MJ. Isokinetic perform-
9. Schatzker J, McMeech R, Bruce D. The tibial plateau fracture: the Toronto expe-
10. Gaston P, Will E, Elton RA, McQueen MM, Court-Brown CM. Analysis of muscle
    function in the lower limb after fracture of the diaphysis of the tibia in adults. \textit{J Bone
11. Kannus P. Normality, variability and predictability of work, power and torque accel-
    eration energy with respect to peak torque in isokinetic muscle testing. \textit{Int J Sports
    strength and muscular endurance for the quadriceps and hamstrings. \textit{Int J Sports
14. Perrin DH, Robertson RJ, Ray RL. Bilateral isokinetic peak torque acceleration
    energy, power and work relationships in athletes and nonathletes. \textit{J Orth Sports Phys
    Ther} 1987;9:184-89.
15. Meighan AA, Keating JF, Will E. Outcome after reconstruction of the anterior cru-
    ciate ligament in athletic patients: a comparison of early versus delayed surgery. \textit{J
16. Finsen B, Harnes OB, Nesse O, Benum P. Muscle function after plated and nailed
17. Damholt V, Zdravkovic D. Quadriceps function following fractures of the femoral