TIBIAL TRANSLATION AFTER ANTERIOR CRUCIATE LIGAMENT RUPTURE
TWO RADIOLOGICAL TESTS COMPARED

HENRI DEJOUR, MICHEL BONNIN

From Centre Hospitalier Lyon-Sud, Pierre-Bénite, France

Anterior tibial translation was measured in both knees using the radiological Lachman test and the lateral monopodal stance tests in 281 patients with unilateral anterior cruciate ligament (ACL) rupture.

Measurements of translation in the medial compartment were more useful than those in the lateral compartment. Measurement of anterior tibial translation in the medial compartment using the radiological Lachman test showed ACL rupture in 92% of cases compared with 70% for the lateral monopodal stance test.

In normal and in ACL-ruptured knees the monopodal stance test showed that every 10° increase in posterior inclination of the tibial plateau was associated with a 6 mm increase in anterior tibial translation; the radiological Lachman test showed a 3 mm increase for every 10° increase in tibial slope.

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Analysis of the forces in the sagittal plane of the extended knee (Williams and Lissner 1977; Nordin and Frankel 1989) shows that they can be resolved into two components, a vertical compression force on the tibial plateau and a shearing force that tends to move the tibia anteriorly. The primary restraint to anterior movement of the tibia is the anterior cruciate ligament (ACL) and rupture of the ACL leads to abnormal anterior tibial translation. This movement can be measured clinically (Hughston et al 1976; Slocum et al 1976; Galway and MacIntosh 1980), by an arthrometer (Harter, Osternig and Singer 1989), or radiologically (Hooper 1986).

We have already described the radiological measurement of anterior tibial translation using the quadriceps contraction technique (Dejour et al 1988a). This technique, called the radiological Lachman test, gives results which compare well with those from a KT 1000 arthrometer (Franklin et al 1991), although the latter measures only passive translation. We now describe another method of measuring anterior tibial translation (ATT) by radiography while the patient stands first on the affected leg and then on the opposite leg; the two are then compared. We call this the lateral monopodal stance test. It attempts to image the knee in a more physiological mode with full vertical compression force on the tibial plateau. It is still not ideal, however, since it is static and not dynamic.

The advantage of radiological methods of measurement over others is that they provide a permanent record as well as a numerical measure. With care it is possible to avoid the problems of rotational malalignment and enlargement. We have used both the radiological Lachman test and the lateral monopodal stance test routinely since 1986 in the investigation of patients with rupture of the ACL.

The importance of the posterior inclination of the tibial plateau (tibial slope) on anterior tibial translation has been demonstrated in dogs by Slocum and Devine (1983, 1984). In cases of rupture of the cranial cruciate ligament, the performance of a tibial osteotomy to change the tibial slope from a mean of 22° to 0° diminished the anterior laxity.

Shoemaker and Markolf (1986) found that in cadaver knees, after division of the ACL and removal of the medial meniscus, vertical compression alone caused the tibia to move forward. This was due, they thought, to the posterior inclination of the tibial plateau.

Dejour et al (1990) reported a case of bilateral congenital absence of the ACL associated with absence of the medial meniscus. Anterior tibial translation was possible to 30 mm, and the tibial slope was 28°. An ACL was constructed using a free graft of the patellar ligament and an extension tibial osteotomy was performed to correct the tibial slope.

We present an analysis of the measurements obtained...
from the radiological Lachman test and the monopodal stance test in cases of ACL rupture. We also report the effects of the tibial slope on anterior tibial translation in normal and ACL-deficient knees.

PATIENTS AND METHODS

Between January 1986 and January 1988, 445 patients were operated on for chronic ACL rupture (more than two months after injury) at the Centre Hospitalier Lyon-Sud. We excluded those with bilateral ruptures (operated or not), those whose treatment did not include a complete intra-articular examination (extra-articular procedures that did not include arthroscopy), and those without adequate notes or radiographs. We therefore studied 281 patients.

There were 171 men and 110 women; their mean age at operation was 25 years (16 to 42). There were 160 right knees affected and 121 left knees. Of these, 228 had not been operated on before, 38 had had one previous operation, 12 had had two, and 3 had had three operations. Medial meniscectomy had been performed in 24 knees, lateral meniscectomy in 6, an extra-articular ACL-plasty in 15, and a synthetic ACL reconstruction in 6.

In 113 patients there was an isolated ACL rupture and in 45 there was also a lesion in the posteromedial corner of the knee. There was rupture of the menisco-tibial fibres in two patients and detachment of the origin of the posteromedial capsule in 43. In these the diagnosis was confirmed by posteromedial arthrotomy. There was a lesion of the medial meniscus in 99 patients: 32 had peripheral detachments, 25 bucket-handle tears, and 18 complex tears (fissuring and flaps of the posterior horn). There were 15 lateral and 9 bilateral meniscal tears.

All the patients had radiological Lachman and lateral monopodal stance tests on both knees.

The lateral monopodal stance test. The patient stands on one leg with the knee flexed to 20° (Fig. 1). The X-ray plate is placed on the inner side of the knee to include 20 cm of the upper tibia on the film. The X-ray source is situated one metre from the knee and is aligned perpendicular to the long axis of the limb. Superimposition of the femoral condyles is obtained by using an image intensifier.

Radiological measurements. All the measurements were made by one observer (MB) and obtained in the same way. A line was drawn on the radiograph perpendicular to the posterior border of the upper tibia to act as a reference for the measurement of anterior displacement. Two lines were drawn parallel to the reference line and tangential to the most posterior part of each femoral condyle (Fig. 2). Two further lines were drawn parallel to the above tangent to the most posterior parts of the medial and lateral tibial plateaux. The lateral femoral condyle is larger and flatter and has the condylo-patellar sulcus in the middle of its curve. The posterior part of the medial tibial plateau is square compared with the lateral which is conical (Jacobsen 1976; Hooper 1986).

The distance between the femoral and tibial lines on the medial side was called the medial anterior tibial translation (MATT) and the distance on the lateral side, the lateral anterior tibial translation (LATT). Comparison between the affected and normal knees gave the differential medial and lateral anterior tibial translations (ΔMATT
and \( \Delta \text{LATTL} \). To distinguish between the results of the radiological Lachman test and the monopodal stance test the suffix -RL or -MS was added, i.e., MATT-RL or MATT-MS.

The posterior inclination of the tibial plateau was measured as follows. The diaphyseal axis of the tibia was drawn between two points equidistant between the anterior and posterior borders of the tibia, one just below the tibial tubercle and the other 10 cm below this. A reference line was drawn perpendicular to this at the level of the tibiofemoral joint (Fig. 3). The inclination of the tibia was drawn from the most superior points at the anterior and posterior edges of the medial tibial plateau (dished surface). The angle of this line to the reference line was defined as the tibial slope.

**Statistical analysis.** All data were stored on an IBM-compatible computer and analysed using the SPSS/PC program. The differences between the various groups were studied using parametric analysis of variance. For comparison of more than two groups, Scheffé’s method of multivariate analysis was used. All the results were recorded as the mean value and standard deviation.

**RESULTS**

Anterior tibial translation was found to vary widely in both the normal and the damaged knees (Figs 4 and 5).

![Graph showing anterior tibial translation measured by the radiological Lachman test on 281 patients.](image)

**Fig. 4**

Translation in the lateral compartment was always larger than in the medial, both in the damaged and the normal knees. The mean difference between the normal and the damaged knees was significant for both compartments of the knee, both for the radiological Lachman test \( (p < 0.001) \) and the monopodal stance test \( (p < 0.01) \). ACL rupture had a proportionately greater effect on the medial than on the lateral side. The mean values of the various radiological measurements for the whole study group are given in Table I.

![Graph showing anterior tibial translation measured by the lateral monopodal stance test on 281 patients.](image)

**Fig. 5**

The difference between normal and damaged knees by the radiological Lachman test, \( \Delta \text{MATT-RL} \), was 2 mm or more in 258 pairs of knees (92%); the \( \Delta \text{LATTL-RL} \) had a difference of 2 mm or more in 205 pairs (73%). The \( \Delta \text{LATTL-MS} \) also had a wider range of values. The \( \Delta \text{MATT-MS} \) was 2 mm or more in 196 pairs of knees (70%); the \( \Delta \text{LATTL-MS} \) was 2 mm or more in 140 pairs (50%).

The mean tibial slope was similar in the normal and the damaged knees (10° ± 3°). There was, however, a
Table 1. Mean values (mm ± SD) for anterior tibial translation measured by the two tests

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Radiological Lachman test</th>
<th>Monopodal stance test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal Ruptured</td>
<td>Normal Ruptured</td>
</tr>
<tr>
<td>MATT*</td>
<td>3.4 ± 2.9</td>
<td>9.0 ± 3.5</td>
</tr>
<tr>
<td>LATT†</td>
<td>8.9 ± 4.0</td>
<td>15.0 ± 5.0</td>
</tr>
<tr>
<td>ΔMATT</td>
<td>5.6 ± 5.8</td>
<td>3.5 ± 3.2</td>
</tr>
<tr>
<td>ΔLATT</td>
<td>6.5 ± 4.4</td>
<td>3.7 ± 5.8</td>
</tr>
</tbody>
</table>

* medial compartment anterior tibial translation
† lateral compartment anterior tibial translation
Δ, difference in translation between normal and ACL-ruptured knee

difference of up to 9° between the two knees of the same patient. There was a highly significant correlation between the mean anterior tibial translation and the tibial slope, both in the normal and in the damaged knees (p < 0.0001) (Fig. 6); the greater the slope the more the tibia translated anteriorly. Linear regression analysis resulted in two separate but nearly parallel lines, one for healthy knees and one for ACL-ruptured knees. For every 10° increase in tibial slope, there was a 6 mm increase in anterior tibial translation on monopodal stance. In the radiological Lachman test, regression analysis showed the same correlation but with only 3.5 mm of increased anterior tibial translation for every 10° increase in tibial slope.

DISCUSSION

Since normal knees show physiological anterior translation it is logical to measure laxity by comparing the ACL-ruptured knee with the contralateral normal knee. As has been found in other studies (Dejour et al 1988b; Reuben et al 1989), measuring the medial tibiofemoral compartment is more useful than measuring the lateral compartment since the range of results is smaller and the effect of an ACL rupture larger on the medial side.

The radiological Lachman test was better than the monopodal stance test in demonstrating a rupture of the ACL (92% of ruptures had a difference of > 2 mm compared with 70%) and we used the latter test more to decide on postoperative management. Patients with a ΔMATT of > 2 mm preoperatively were non-weight-bearing on the injured leg for 45 days; those with ΔMATT of < 2 mm were allowed to bear weight immediately after the operation.

It is clear that one of the factors affecting the anterior translation of the tibia is the slope of this plateau. Even in normal knees the laxity increases in proportion to the slope of the tibia, and at the same rate as in ACL-ruptured knees; loss of the ACL simply increases the displacement by an absolute amount. The forces on the knee during weight-bearing can be resolved into a vertically directed compression component, and a horizontally directed shear component; it is the shear component that varies with the tibial slope (Shoemaker and Markolf 1986).

The normal knee is lax, but not unstable. Excessive laxity (in extension) is probably the mechanism that leads to osteoarthritis in ACL-ruptured knees (Dejour et al 1987, 1988b) but reconstructing the ACL can hasten rather than delay the onset of osteoarthritis (Feagin, Cabaud and Curl 1982; Bartlett and Crow 1984; Johnson et al 1984; Fried et al 1985; Zarins and Rowe 1988).

Goutallier et al (1986) and Hernigou et al (1987) reviewed series of patients undergoing valgus tibial osteotomy for medial compartment osteoarthritis, and found that those with a tibial slope of 10° to 15° had central plateau erosions, whereas those with 18° to 25° had posterior erosions. They measured the slope by Moore's technique (Moore and Harvey 1974) which gives a normal value of 14°. In cases of excessive slope, the osteotomy did not halt the progress of the arthritis, suggesting that in those knees it may be necessary to perform both extension and valgus tibial osteotomy.

Conclusion. Anterior tibial translation secondary to ACL
rupture is recorded and measured radiologically better on the medial than on the lateral side of the joint. The radiological Lachman test is of more value than the lateral monopodal stance test in demonstrating rupture of the ACL.

When weight-bearing, every 10° increase in tibial slope is associated with a 6 mm increase in anterior tibial translation, both in normal knees and in those with a ruptured ACL, but the magnitude of the displacement is greater in the latter.

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REFERENCES