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Instability of knees with ligament lesions

Cadaver studies of the anterior cruciate ligament

We studied the importance of the two parts of the anterior cruciate ligament (ACL), the medial collateral ligament (MCL), and the posterior medial capsule (PMC) to translatory and spontaneous axial rotatory instability in 15 osteoligamentous knee preparations. Instability was recorded continuously from zero to 90 degrees of flexion with application of a constant force to the tibia. Isolated cutting of the ACL caused a moderate anterior translatory movement, which increased if the MCL was also cut. Transection also of the PMC resulted in an even larger range of anterior translatory movement. Combined lesions to the MCL and the PMC and the posterolateral part of the ACL did not cause such instability provided the anteromedial part of the ACL was intact.

Application of a valgus moment to specimens with injured ACL and medial structures induced a spontaneous anteromedial subluxation of the tibia in a semiflexed position. When flexion was increased to 70–80 degrees, a sudden reduction was observed

Strange Nielsen
Peter Helmig

Biomechanics Laboratory, Orthopaedic Hospital, Randersvej 1, DK-8200 Aarhus N, Denmark

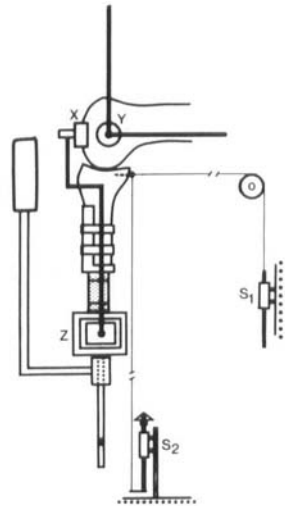
Pathological anterior displacement of the tibia is a complex movement composed of a pure translatory movement and a simultaneous axial tibial rotation, depending on the ligamental structures involved in the lesions. Our purpose was to evaluate the stabilizing function of the two parts of the ACL, the anteromedial (AMP) and the posterolateral (PLP), and the medial ligamentary structures by continuously recording the anterior tibial displacement and axial rotation during extension-flexion from zero to 90 degrees of flexion with application of a constant anterior-posterior directed force to the rotationally unrestrained tibia.

Material and methods

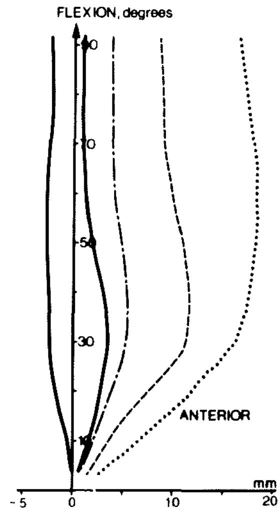
The experiments were carried out on 15 normal osteoligamentous preparations obtained at autopsy and immediately deep-frozen to −25°C. All dynamically stabilizing structures were removed, but the menisci, the cruciate ligaments, the collateral ligaments, and the posterior joint capsule with its posterior oblique, popliteal oblique, and popliteal arcuate ligaments were preserved. The experimental method and set-up was previously described by Nielsen et al. (1984) and only the technical refinement of the apparatus will be described.

Anterior-posterior tibial displacement was measured by two sliding potentiometers connected by threads normal to each other at a central point of the posterior side of the tibia just distal to the insertion of the posterior cruciate ligament (Figure 1). After determination of the neutral position by unloaded tibial movements during extension-flexion, the displacement "d" could be calculated from $d = \sqrt{s_1^2+s_2^2}$, where s_1 and s_2 were the relative movements registered by the two potentiometers during application of an anterior or posterior force to the tibia. The corresponding tibial axial rotation was registered by the potentiometer marked "Z" (Figure 1).

The anterior-posterior force was applied by a handle fitted to the lever terminating in a ball-bearing, allowing the tibia to rotate freely. The force was applied manually at the level of the joint and the knee joint was moved from extension to 90 degrees of flexion and back again with application of an anterior and posterior force, respectively. The force "f" was calculated from $f = \sqrt{x^2+y^2}$, where x and y were the forces measured by the strain gauges normal to each other in the anterior-posterior and medial-lateral plane. Signals from strain gauges and potentiometers passed through an amplifier and a data acquisition system to a microcomputer. The results were calculated for a force of exactly 25 N and computation of the final mobility patterns (Figure 2) was performed at a regional computer service center (RECAU). All curves were recorded with the tibia in a neutral position with regard to the valgus-varus angulation, and free axial rotation was allowed.



◄ Figure 1. Schematic experimental set-up. Knee flexion angle, valgus-varus movement, and axial tibial rotation are measured by the potentiometers marked Y, X, and Z, respectively. The relative movements of the potentiometers S_1 and S_2 reflect the anterior-posterior tibial displacement. Strain gauges placed just distal to the tibial segment measure torque. The handle terminates in a ball-bearing, allowing the tibia to rotate freely when an anterior-posterior force is applied.



► Figure 2. Mobility pattern from the 2nd experimental series showing anterior-posterior displacement caused by the ligament transections. ——— Intact ligaments. — · — AMP of ACL. - - - - ACL (+ PMC) cut. • • • Plus MCL cut.

Stability was recorded in three series, each comprising five preparations:

First series: (a) ligaments intact; (b) MCL cut; (c) MCL and AMP cut; (d) MCL and ACL cut.

Second series: (a) ligaments intact; (b) AMP cut; (c) ACL cut; (d) ACL and PMC cut; (e) ACL and PMC and MCL cut.

Third series: (a) ligaments intact; (b) PMC cut; (c) PMC and MCL cut; (d) PMC and MCL and PLP cut; (e) PMC and MCl and ACL cut.

A paired Student's *t*-test was used for comparison of the results.

Results

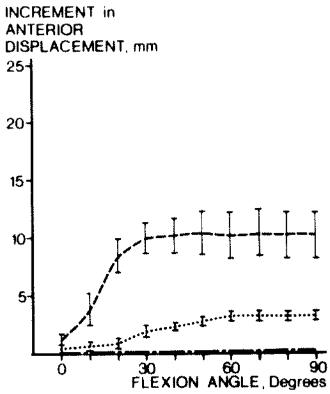
Anterior displacement was not affected by transection of the MCL and only moderately increased by additional cutting of the AMP, most pronounced in the flexed position (Figure 3). Combined lesions to the MCL and the ACL caused an anterior instability during the whole range of motion, rapidly increasing from extension to 30 degrees of flexion. The instability of 10 mm remained constant during further flexion (Figure 3).

In the second series isolated section of the AMP caused a minor increase of anterior displacement in a flexed position of the same amount as with combined transection of the AMP and the MCL. The anterior tibial movement increased with flexion to a maximum of 6 mm at 35 degrees of flexion by cutting of the ACL (Figure 4). The instability decreased during further flexion. With transection of the PMC with the MCL intact, only a minor increase in the instability was noted in the area of maximal instability, i.e. 30–40 degrees of flexion. When transection also included the MCL, the anterior displacement increased markedly during the whole range of motion, mostly from 60 to 90 degrees of flexion.

Anterior tibial displacement remained largely unaffected after combined transection of all the medial structures and the PLP in the third experimental series (Figure 5). A marked increase was observed only when the AMP was included, increasing the displacement from 4 to 20 mm at 60 degrees of flexion.

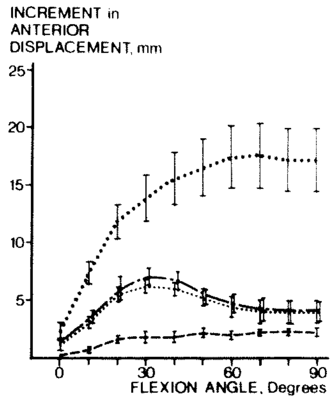
No changes in the posterior tibial displacement were observed in the experimental series.

Isolated cutting of the MCL, PMC or ACL did not cause any changes in simultaneous tibial rotation. Combined transection of the medial structures leaving the ACL intact induced a small increase in external rotation of 3 degrees because of the anteromedial instability, which was constant during the whole range of motion and unaffected by additional cutting of the PLP. Combined section of the MCL and the AMP resulted in an increased external rotation in the flexed postion (Figure 6). This insta-



◀ Figure 3. Increment in anterior displacement related to the degree of flexion from the 1st experimental series. The inaccuracy is stated as the standard error of the mean.
— —— - — MCL cut.
.... MCL + AMP cut.
-------- MCL + ACL cut.

Figure 4. Increment in anterior displacement related to the degree of flexion from the 2nd experimental series. ▶
--------AMP cut.
.............ACL cut.
— — - — ACL + PMC cut.
• • • • • • • • •ACL + PMC + MCL cut.



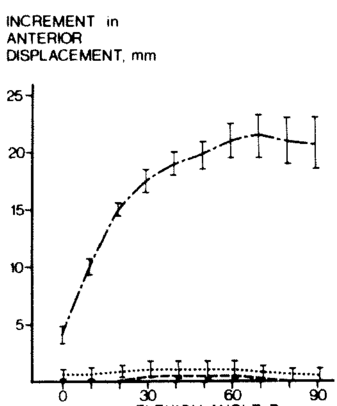
bility increased if the ACL was entirely transected. However, changes in tibial rotation in the extended-semiflexed postition of the knee were still not recorded due to the intact PMC. Including the PMC, the passive external tibial rotation increased from extention to 90 degrees of flexion to a maximum of 25 degrees.

Application of an anterior force to the flexed knee with injured ACL and MCL incarcerated the posterior horn of the medial meniscus due to the anteromedial subluxation of the tibia.

A valgus moment with transected medial structures, and including an ACL lesion, caused a simultaneous anteromedial rotation of the tibia in semiflexed knees. By further flexion to 70–80 degrees, the displacement was suddenly reduced due to a posterior movement of the articulating point on the lateral tibia plateau, releasing a "reverse medial pivot shift". In this position the posterior cruciate ligament limits valgus instability and thus constitutes the axis of rotation.

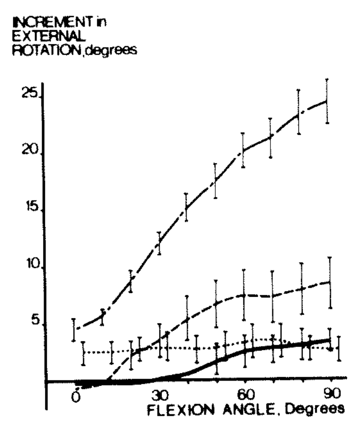
Discussion

Our experiments showed that the ACL, and particularly the AMP, is the primary stabilizer as regards the anterior drawer movement between zero and 90 degrees of flexion, which was also emphasized by Furman et al. (1976) and Dorlot et al. (1983). They concluded that the anterior drawer sign cannot be obtained unless the AMP is severed. Hughston et al. (1976) examined 26 anaesthetized patients with medial tears but intact ACL and found a positive anterior drawer sign with the tibia in external rotation in 77 per cent of the patients, concluding that the medial joint capsule is the first line of defence against anterior instability. We do not agree with this statement, as they tested only anteromedial instability. The possible role of an additional, purely anterior displacement would not be revealed because of the relaxed ACL in the position of externally rotated tibia (Kennedy et al. 1977) when the



◀ Figure 5. Increment in anterior displacement related to the degree of flexion from the 3rd experimental series.
--------PMC + MCL cut.
...........PMC + MCL + PLP cut.
— — — —PMC + MCL + ACL cut.

Figure 6. Spontaneous external axial rotation caused by an anterior force related to the degree of flexion. ▶
———— AMP + MCL cut.
. . . . PMC + MCL cut.
- - - - - - MCL + ACL cut.
— — — - - PMC + MCL + ACL cut.



medial structures are intact. Slocum & Larson (1968) found that when the foot is placed in 15 degrees of outward rotation and the tibia is pulled forward, rotatory stress is placed first on the medial joint capsule, then the MCL, and finally on the ACL. The movement was a combination of a purely forward displacement of the tibia and an anteromedial subluxation. Slocum & Larson stated that with small degrees of forward dislocation, false positive anterior drawer tests are usually due to the rotational element associated with ruptures of the medial capsule. In the present study lesions to the medial structures did not cause forward tibial displacement, but only external rotation when an anterior force was applied. With isolated injury to the ACL, we noticed a maximum increment in anterior displacement at 35 degrees of flexion without tibial rotation, and the movement was thus purely translatory. This suggests that during the clinical examination the best position for anterior drawer testing is 35 degrees of flexion and a neutral tibial position. We found only that very small differences between intact knees and those with sectioned ACL occurred at full extension. This disagrees with Markolf et al. (1976), who tested cadaver knees at zero, 20, 45, and 90 degrees of flexion using a force of 100 N. Isolated section of the ACL produced the greatest increase in anterior-posterior laxity at full extension (× 2.7). The tests were performed with the tibia fixed in neutral position with respect to axial rotation, which may explain the divergence. By combined transection of the medial compartmental structures and the ACL, the markedly increased anterior displacement and external rotation in flexed position suggest that clinical detection of such lesions would require the anterior drawer test to be performed at 60 degrees or more of flexion with the tibia free to rotate or, alternatively, in externally rotated position. These results do not agree with those of Kennedy & Fowler (1971). In patients with ACL and medial compartment tears, they found a displacement of the lateral tibial condyle corresponding to that of the medial condyle as verified by stress roentgenograms, and they consequently concluded that rotary instability did not exist. Similarly, by testing cadaver knees on a knee-stiffness apparatus, Sullivan et al. (1984) found that fixed external rotation of the tibia did not change the anterior displacement in the knee. However, they compared their results to the situation where the tibia was allowed to rotate freely.

Acknowledgements

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