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Instability of cadaver knees after transection of capsule and ligaments

The importance of the medial collateral ligament and the anterior cruciate ligament of the knee in relation to valgus and varus instability was investigated. Mobility patterns were drawn from ten osteoligamentous knee preparations after successive transections of the structures. Cutting the entire collateral medial ligament caused only slight valgus instability, even when the knee was flexed. Further transection of the anterior cruciate ligament increased the instability considerably, but the knee remained stable in extension. The valgus instability after the transections was maximal at about 60° of flexion.

Key words: biomechanics; knee joint; ligaments, articular.

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Various attempts have been made to elucidate biomechanically the instability of the knee after various types and combinations of ligament injuries (Markolf et al. 1976, Seering et al. 1980, Noyes et al. 1980, Lipke et al. 1981, Grood et al. 1981). In these studies, however, the torque was not well-defined or else the instability was recorded at only a few positions during the extension-flexion movement of the knee joint.

The object of the present investigation was to study the role of the medial-compartment ligaments, posterior medial capsule, and anterior cruciate ligament in stability. To this end, an apparatus was developed which enables a continuous registration of the varus-valgus instability in the extension-flexion movement of the knee in the area 0°–150° during a well-defined, constant torque.

Material and method

The experiments were carried out on 10 osteoligamentous preparations, which were macroscopically normal and had been obtained from amputated legs deep frozen immediately after amputation.

When the knees were dissected, the menisci, cruciate ligaments, collateral ligaments, and the posterior capsule – including the posterior oblique, popliteal oblique, and popliteal arcuate ligaments – were preserved.

The preparation was suspended in the femur, which was fixed horizontally. A lever directed toward the intercondylar tibial eminence was fixed to the distal end of the tibial segment. This lever was fitted with two strain gauges, at right angles to each other, to measure the torque in two planes. Rotatory angulations were measured by two potentiometers at right angles to each other and fixed to the lever so that they were situated at the axis of flexion-extension of the knee.

Signals from the strain gauges and potentiometers passed through an amplifier (Figure 1) to two X–Y writers which recorded the magnitude and direction of the torque and traced a movement curve, respectively. At the same time, the signals were passed through a data acquisition system to a microcomputer (RC 702) which stored the results of the measurements on floppy discs. From there, they were transmitted, through the telephone network, to a regional computer service centre (RECAU) where the final movement curves were calculated for 2 Nm and plotted.

We preferred to keep the torque constant and we found that an action of 2 Nm was suitable, as it does not overstrain the ligaments and capsular compartments.

The lever was operated manually, and the magnitude of the torque was secured by zig-zagging the pen on the torque writer over a square corresponding to the selected action of 2 Nm, so that the action varied between being a little over and a little under

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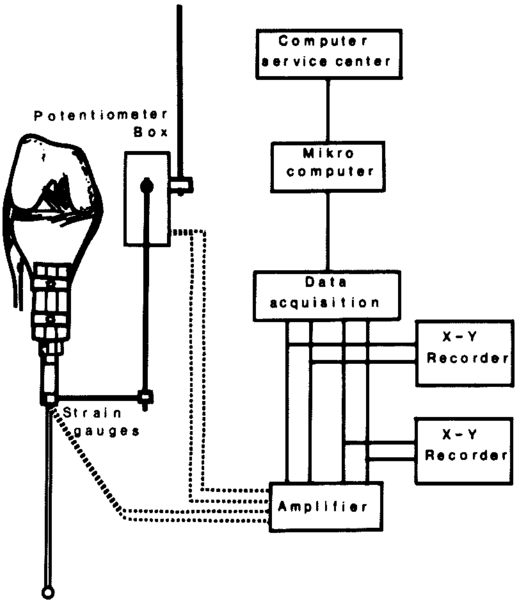

Figure 1. Schematic experimental set-up.

the 2 Nm. Appurtenant rotatory angulations were recorded and stored by the computer.

The knee joint was moved from extension to flexion and back, partly during varus and partly during valgus torque.

In the first experimental series, comprising five preparations, registration of the stability was done at the following ligament status: 1. Intact ligaments. 2. Anterior third of the medial collateral ligament cut. 3. Anterior two-thirds of the medial collateral ligament cut. 4. The entire medial collateral ligament cut. 5. The posterior capsule, including its ligament reinforcements, viz. the posterior oblique and popliteal oblique ligaments, cut. 6. Further, the anterior cruciate ligament cut.

In the second experimental series, comprising the remaining five preparations, the measurements were made as follows: 1. Intact ligaments. 2. Posterior capsule cut. 3. + posterior third of the medial collateral ligament cut. 4. + posterior two-thirds of the medial collateral ligament cut. 5. + the entire medial collateral ligament cut. 6. + the anterior cruciate ligament cut.

The medial collateral ligament and the posterior capsule were cut at the level of the joint line over the meniscus.

Results

Figure 2 depicts an example of a curve traced from the first experimental series. The extension-flexion movement of the knee is recorded along the Y axis, full extension corresponding to 0°. The curves were truncated at 150°, as any further possibility of flexion in the preparations is not of any practical relevance. Valgus indicates the lateral and varus the medial movement of the tibia.

In the first experimental series, sectioning of the anterior third of the medial collateral ligament did not cause any increase in valgus instability. After cutting two-thirds of this ligament there was also no instability, and it was not until the entire medial collateral ligament had been cut that a slight valgus instability was found. On further cutting of the

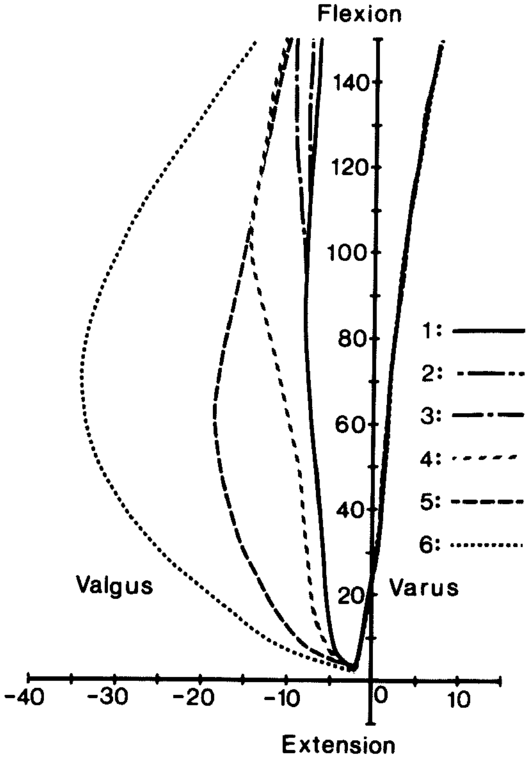

Figure 2. Mobility pattern from the 1st experimental series. The first three curves (1: intact ligaments, 2: anterior one-third and 3: anterior two-thirds of the medial collateral ligament) coincide. Then follow, with increasing valgus instability, curve 4: total medial collateral ligament cut, curve 5: + the posterior capsule, and curve 6: + the anterior cruciate ligament cut.

Table 1. The increase in valgus instability (mean ±SD) in the 1st experimental series at 30° and 60°, respectively, of flexion

	30°	60°
1/3 of medial coll. lig. cut	0°	0°
2/3 of medial coll. lig. cut	0°	0.2°±0.5°
Entire medial coll. lig. cut	2.0°±0.7°	2.4°±1.1°
Posterior capsule cut	7.6°±1.5°	8.6°±2.1°
Ant. cruciate lig. cut	17.0°±4.1°	23.6°±3.1°

Table 2. The increase in valgus instability in the 2nd experimental series at 30° and 60°, respectively, of flexion

	30°	60°
Posterior capsule cut	0°	0°
Post. 1/3 of med. coll. lig. cut	0.8°±0.5°	0.2°±0.5°
Post. 2/3 of med. coll. lig. cut	2.2°±1.8°	1.6°±1.1°
Entire medial coll. lig. cut	7.0°±2.7°	8.0°±2.1°
Ant. cruciate lig. cut	13.4°±2.1°	19.0°±2.4°

posterior capsule appreciable valgus instability occurred and, lastly, on cutting the anterior cruciate ligament a marked increase of the valgus instability was noted (Table 1).

In the second experimental series (Figure 3), no medial-lateral instability occurred on sectioning the posterior capsule, and a slight valgus instability was first noted after cutting the posterior two-thirds of the medial collateral ligament.

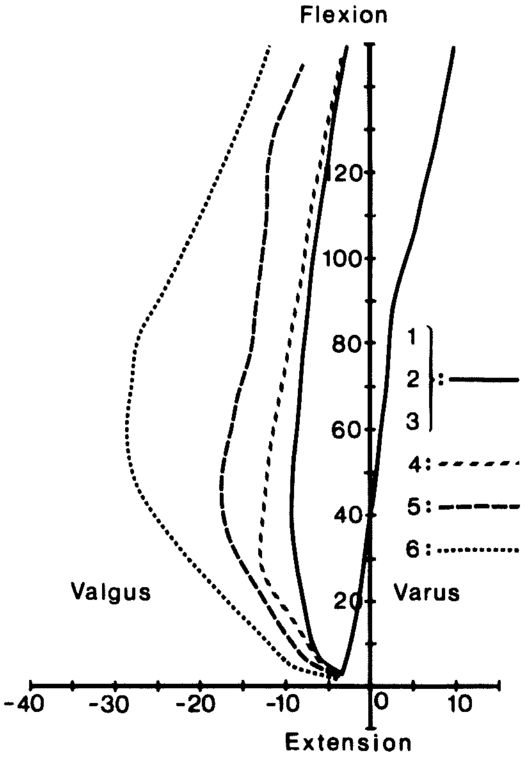

Figure 3. Mobility pattern from the 2nd experimental series. The first three curves (1: intact ligaments, 2: posterior capsule and 3: + posterior one-third of the medial collateral ligament) coincide. Then follow, with increasing valgus instability, curve 4: further cutting of the posterior two-thirds of the medial collateral ligament, curve 5: + the entire medial collateral ligament, and curve 6: + the anterior cruciate ligament cut.

After cutting the entire collateral ligament, a good correlation to the appurtenant valgus instability was recorded in the first experimental series and finally, when the anterior cruciate ligament was also cut, the instability was considerably increased (Table 2).

It is apparent from the curves that after sectioning both ligaments and the posterior capsule a slight increase of 2–5° occurs in the extension ability and that at extension there is still complete lateral-medial stability in the joint. Moreover, the curves demonstrate that the greatest valgus instability appears around 60° of flexion.

Discussion

Brantigan & Voshell (1941), using a torque of 3.5 Nm on osteoligamentous preparations, found no increase in varus-valgus instability after cutting the medial collateral ligament or the anterior cruciate, whereas a combination of these injuries caused marked valgus instability. This is in agreement with our findings, but they did not mention the posterior capsule.

Hughston et al. (1976), reporting the clinical examination and operative findings in 68 knees, observed valgus instability at 30° flexion after injury to the medial-compartment ligaments, but stability in extension. This also applied to anterior cruciate ligament tears. The same was found by us, but we demonstrated that a combined injury to the medial collateral ligament and the posterior capsule is decisive in causing valgus instability. Hughston et al. concluded that the posterior part of the capsule has no influence on stability at 30° of flexion. We deduce from our investigations that, as regards the total mobility of the knee joint, isolated injury to either the medial collateral ligament or the posterior capsule causes only slight varus-valgus instability, whereas a combination of the two injuries gives rise to appreciable instability in the total movement, the knee then being stable only in extension.

Markolf et al. (1976), studying 35 cadaver knees in six positions of flexion, used a torque of 29 Nm to affect varus-valgus stability. Considerable valgus laxity resulted from isolated cutting of the medial collateral ligament in which, however, they included the posterior oblique ligament. They also found varus-valgus instability at 4.3° extension after this injury, and the increase in valgus instability was most marked at full extension. Furthermor, Markolf et al. found no difference in valgus instability between isolated injury to the medial collateral ligament and a combined injury to this ligament and the posterior capsule. This finding, which differed from ours, may presumably be explained partly by their inclusion of the posterior oblique ligament in the medial collateral complex and partly by the great torque used by them.

Seering et al. (1980) loaded two cadaver knees with up to 48 Nm in valgus-varus to assess the relative role of the ligaments. Like us, they reported that the anterior cruciate proved of no importance to valgus laxity in extension, but unlike us they also found it to be of relatively little importance in 30° of flexion. Similarly, they found the posterior part of the of the capsule to be of no actual importance to stability, at full extension as well as at 30° of flexion. This is at variance with our experiments in which combined injury to the medial ligament complex and posterior capsule proved to be of decisive significance to the magnitude of the valgus instability. The divergence may presumably be explained by the marked difference in the torque used.

Grood et al. (1981), investigating 16 cadaver knees at 5° and 25° flexion, found a valgus-varus torque of 18 Nm to result in valgus laxity of 3° after cutting the medial collateral ligament. This agrees with our findings.

Girgis et al. (1975) reported a study of the anatomy and role of the cruciate ligaments in 44 knees. They observed an average hyperextension of 25°, caused by cutting the anterior cruciate ligament. The torque action was not recorded, but is stated to have been the maximum manual force by which the examiner could affect the knee. This amounts to quite considerable force and could explain the marked divergence in the findings from our few degrees of increased extension after cutting all the ligaments in question.

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