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THE LATERAL STABILITY OF THE KNEE-JOINT

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Opinions are divided on the manner in which the lateral stability of the knee-joint should be examined and on the implications of any lateral instability found. We have studied this problem in the clinic and on autopsy specimens and our findings are reported in this article.

PREVIOUS STUDIES

Chapchal (9), the author of the only monograph on methods of orthopaedic examination, stated in 1954 that in an examination for any lateral instability the knee-joint should be fully extended. Lateral instability was ascribed to damage to the collateral ligaments and said to be proportional to the severity of the injury. Similar opinions have been expressed in a number of the major text-books on orthopaedics (2, 3, 10, 19, 23, 24) in monographs on the knee-joint (5, 21) and articles in journals (13, 16). There is thus a general view in the orthopaedic and surgical literature that the injuries to the collateral ligaments should be examined with the knee fully extended and that any instability in this position is a sign of damage primarily to the tibial collateral ligament.

A different view has been expressed by some authors, namely that the knee is stable in extension even if the tibial collateral ligament is severed, but as *Palmer* (17, 18) writes, "If the instability continues in hyperextension, this must be interpreted as a sign of insufficient tension of the crucial ligaments". *De Palma* (11, 12) too, asserts that lateral instability of the knee in extension can be present only if damage to the tibial collateral ligament is associated with injury to the anterior cruciate ligament. This opinion is shared by *Brantigan & Voshell* (6), *Böhler* (7), *Casagrande & Frost* (8), *Hult* (12) and *Smith* (22).

Abbott et al. (1), who examined 6 knee-joints in connection with the division of various ligaments, gives an apparently contradictory account of his findings relating to lateral instability. First it is stated that no lateral instability was obtained even when both the tibial collateral ligament and the anterior cruciate ligament were divided, and then that lateral instability in hyperextension, when present, was due to division of both the tibial collateral and the anterior cruciate ligaments. A similar contradictory view is expressed by *Bohn & Lyck* (4) on the basis of experiments on 4 knee-joints. They assert that it is impossible to obtain lateral instability in extension even when the medial collateral and anterior cruciate ligaments are divided, but in the discussion they say that if there is such lateral instability it is likely that both these ligaments are ruptured. *Saugmann-Jensen* (20) states on the basis of tests on a single knee specimen that "true" lateral instability is obtained only when the tibial collateral and anterior cruciate ligaments and the posterior capsule have been divided, but that a moderate instability is obtained in extension when only the two ligaments have been divided.

Thus, three contradictory views can be distinguished in the literature as regards the importance of the tibial collateral ligaments to lateral instability.

(1) Lateral instability is due to rupture of the tibial collateral ligament, and the examination must be made in extension. This is probably the method now most commonly taught to students and specialists alike.

(2) Lateral instability in extension is due to rupture of both the tibial collateral and the anterior cruciate ligaments.

(3) There is generally no lateral instability in extension when the tibial collateral and cruciate ligaments are divided, but if such instability in this position should be found these injuries can be assumed to be present.

NOMENCLATURE

The terminology in the literature referred to is varied and obscure. The knee-joint is commonly taken to be extended at an angle of 180°. This position is referred to variously as full extension, extension, mid-position, etc. Further extension is referred to as maximum extension and hyperextension, but sometimes extension or full extension. There is usually no indication of which position is intended, and this is probably one reason why statements in the literature are controversial.

It would seem logical from the functional standpoint that the knee should be considered extended when there is resistance to further extension, whether this occurs at an angle between the thigh and lower

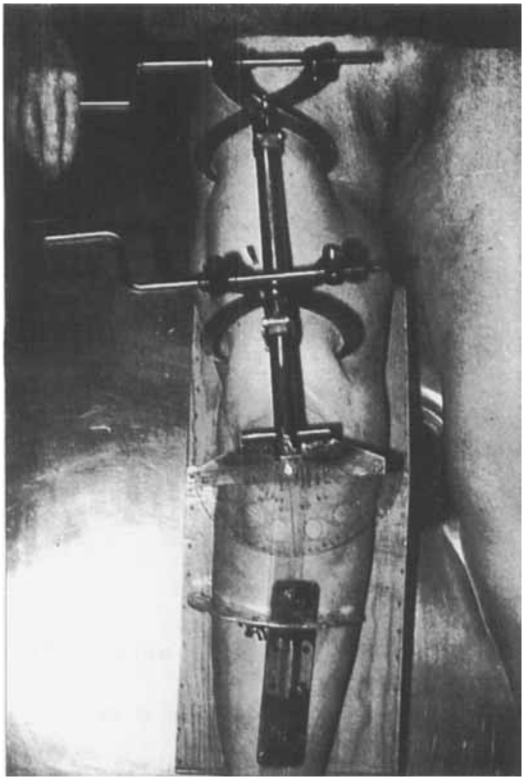

Fig. 1.
Apparatus for measuring the lateral mobility and rotation of the knee-joint.

leg of 180, 185 or 190°. The axes of these more or less curved bones, surrounded by soft tissues of widely varying form, can be difficult both to define and to measure. In the following the term *extension* denotes the position in which the knee is extended to the point where there is resistance to further extension.

MATERIAL

The study was performed on 16 knee joints from autopsy cases and on some 50 knee-joints of out- and in-patients. The age and sex distributions for the autopsy cases were as follows:

Age	< 40	40–60	> 60
Men		4	3
Women	1	2	6

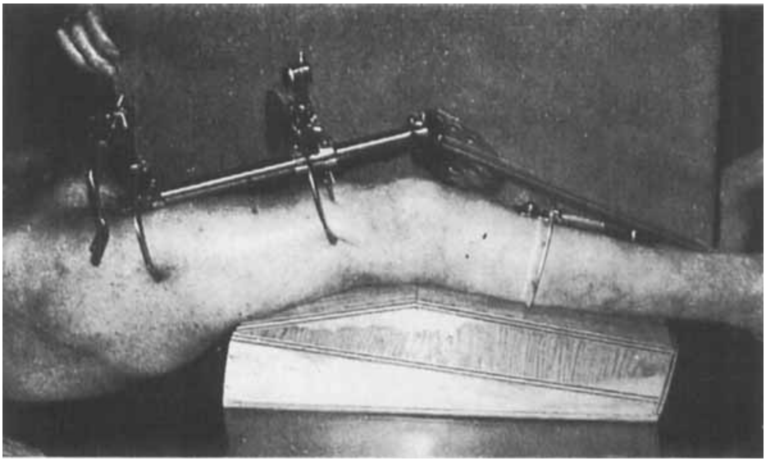

Fig. 2.
Apparatus for measuring the lateral mobility and rotation of the knee-joint. The joint is held in the 160° position by a special frame.

METHODS

For the laboratory studies an apparatus was designed one part of which was fixed to the femur and the other to the tibia (Fig. 1).

The lateral stability of the knee-joint could be read off in degrees in any desired position of flexion.

This apparatus and a uniform examination technique were developed and standardized in preliminary experiments on 5 knee-joints. A further 11 joints were tested systematically.

After rigor mortis had been broken the lateral instability was recorded for the intact knee first in the extended position and then slightly flexed, with an angle of about 160° (Fig. 2). The superficial and deeper portions of the tibial collateral ligament and the anterior and posterior cruciate ligaments were divided in turn. After each division the lateral stability was tested in the two positions. For two joints the lateral instability was also tested after the posterior capsule with its ligaments had been divided. In the tests one examiner supported the thigh fixation device and took the readings while the other manipulated the lower leg with as far as possible equal force in the different experiments, and without seeing the scale. In spite of this fairly standardized technique it proved difficult to obtain accurately reproducible values. This was because of the elasticity of the tissues and the difficulty in applying a constant force to the knee. Owing to difficulty in determining accurately or defining the mean or neutral position, the lateral instability was not divided into abduction and adduction.

For the examination of the patients the usual clinical and radiographic methods were used. In the tests of lateral instability the patient's foot was held by the examiner between the elbow and trunk so

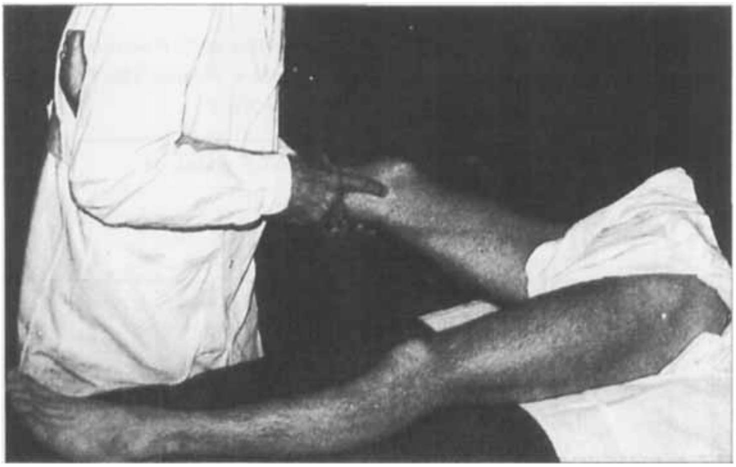

Fig. 3.
The grip for examining the lateral mobility of the knee-joint.

that both hands were free to hold the knee in the required flexed position while moving the knee in ab- and adduction (Fig. 3).

RESULTS

Irrespective of whether the knee was intact or the ligaments were divided, none of the 55 tests (5 tests on each of 11 cases) on autopsy specimens displayed lateral instability in extension. Sometimes, however, there was a swing of a few degrees on the scale if a large force was applied, but this was the same for intact knees and when all the ligaments had been severed. Only when the posterior capsule had been divided as well as the tibial collateral and cruciate ligaments was the stability of the joint impaired, and then to such an extent that it could be moved freely in any direction. For intact knee-joints the average lateral instability in the 160° position—that is, with the knee flexed 20°—was 9°, with a range of 8–13° (Table 1). When the superficial portion of the tibial collateral ligament was severed the lateral instability increased to an average of 13°, and on division also of the deep portion it was increased to 15°. The division then of the anterior cruciate ligament gave a lateral instability of 18°, and when the posterior cruciate was divided the total lateral instability on an average was 21°. Thus the lateral instability increased a few degrees as each of the ligaments was divided.

TABLE 1
Lateral Mobility (in Degrees) of 11 Knee-Joints in the 160° Position after Division of the Ligaments in Turn. The Figures in Parentheses Denote the Incrase Relative to the Value for the Intact Knee.

Intact knee	Mobility on division in turn, of			
	Tibial coll. lig.		Cruciate lig.	
	Superfic.	Deep	Ant.	Post.
10	14 (4)	17 (7)	21 (11)	24 (14)
9	12 (3)	14 (5)	16 (7)	20 (11)
9	11 (2)	11 (2)	13 (4)	18 (9)
13	14 (1)	17 (4)	19 (6)	20 (7)
8	13 (5)	20 (12)	25 (17)	25 (17)
9	14 (5)	17 (8)	21 (12)	26 (18)
9	14 (5)	18 (9)	20 (11)	27 (18)
8	12 (4)	16 (8)	17 (9)	19 (11)
9	13 (4)	12 (3)	16 (7)	15 (6)
8	9 (1)	9 (1)	12 (4)	19 (11)
12	13 (1)	16 (4)	17 (5)	18 (6)
Mean 9	13 (4)	15 (6)	18 (9)	21 (12)
Range 8–13	9–14	9–20	12–25	15–27

Concurrently to this study special attenion was given to the clinical cases of knee disorders due either to injury or osteoarthritis. A number of cases of damage to the tibial collateral ligaments were diagnosed in which there was a definitely greater lateral instability than on the healthy side when tested in slight flexion: in extension, however, all these knees were stable. At the same time 7 cases with a marked instability in extension were examined; 2 of these were cases of femoral condyle fracture. In one of them the femoral condyle was found at autopsy to be displaceable one centimetre and this resulted in an instability of 20° in extension. In 2 cases the movement was due to recent fracture of the tibial condyle (Fig. 4), and in 3 cases to severe osteoarthritis, with destruction of one of the tibial condyles (Figs. 5–7). In a further case with similar lateral instability after an acute abduction trauma there was no radiologic evidence of a fracture; surgical exposure of the tibial collateral ligament and condyles disclosed an intact ligament but a definite depression of the lateral tibial condyle.

In all the clinical cases of instability in extension there was thus a loss of substance in the condyles.

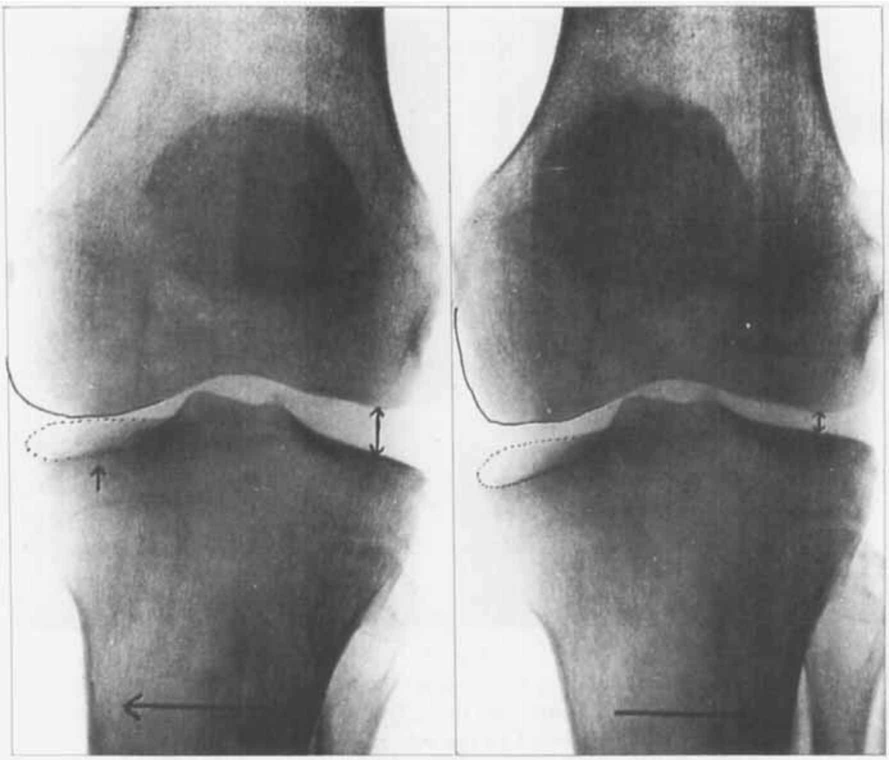

Fig. 4.
Radiographs of the knee-joint in a compression fracture in the medial condyle of the tibia. The mobility of the knee-joint in extension is represented in the two radiographs.

THE MECHANICS OF LATERAL INSTABILITY

In extension of the knee the four condyles are pressed against one another with a force that is proportional to that with which the knee is extended (Fig. 8). The force is transmitted to the condyles as in a pair of nut-crackers, through the resistance presented by the posterior capsule (Fig. 8 a). This capsule, strong in itself, is reinforced by a number of smaller ligaments and tendons and offers a firm resistance to over-extension. So long as the joint is extended and thus the posterior capsule is tense, it is mechanically impossible to bend the knee laterally irrespective of whether there are stabilizing structures at the sides or in the middle of the joint (Fig. 8 b). So long as the force extending the knee exceeds that tending to cause a lateral movement the 4 condyles will be pressed together.

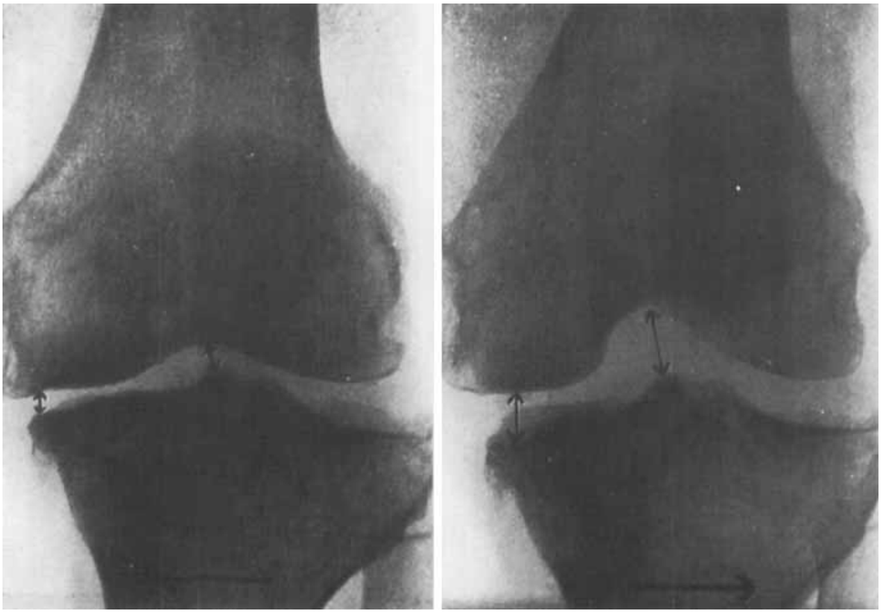

Fig. 5.
Radiographs of the knee-joint in a severe case of osteoarthritis and loss of substance in the medial condyles of the femur and tibia. The mobility of the knee in extension is represented in the two radiographs.

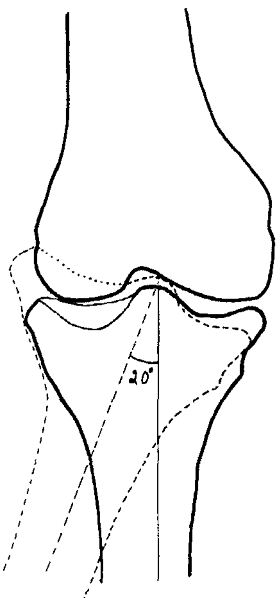

Fig. 6.
Tracing of radiographs of the knee-joint with a lateral mobility of 20° in extension owing to severe osteoarthritis and loss of substance in the medial condyles of the femur and tibia. The dotted line indicates the position of the knee-joint on adduction in extension.

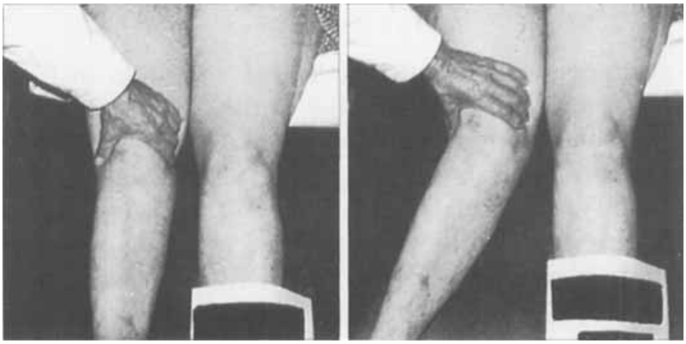

Fig. 7.
Knee-joint with marked lateral mobility in extension. The radiograph shows osteoarthritis and loss of substance in the lateral condyles of the femur and tibia.

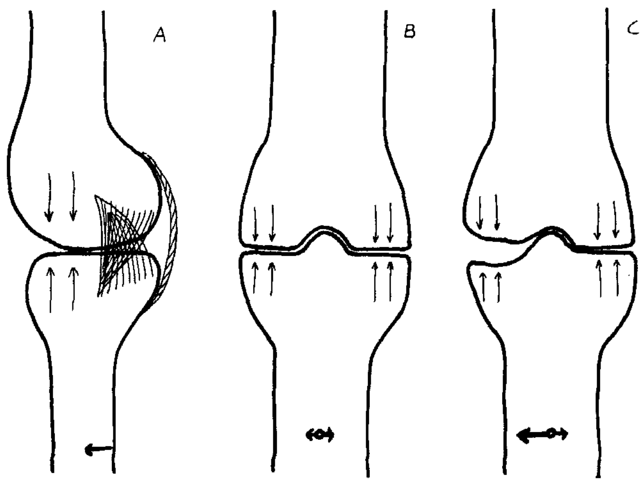

Fig. 8.

A. The knee-joint in extension. The condyles are pressed together when the posterior capsule is stretched.
B. In extension with the condyles pressed together the knee is stable in the lateral direction.
C. When there is a loss of substance in the condyles there may be lateral mobility in extension. This is not prevented by intact ligaments.

Hence, so long as the two condyles on each side of the knee joint are in contact there can be no lateral movement in the extended position. If any of the condyles is subjected to loss of substance these mechanical conditions are disturbed, and even in extension two positions of equilibrium are obtained between which movement can take place (Fig. 8 c).

DISCUSSION

In this study we have found that lateral instability in extension is typical of cases in which there is a loss of substance in the condyles of the knee-joint, but not a symptom of damage to the ligaments. This is supported by the analysis of the purely mechanical conditions for lateral instability. That this situation has not been demonstrated previously may be ascribed to the fact that in cases of acute injury lateral mobility is sometimes found in extension because of damage to the posterior capsule and compression fractures of the condyles, which have not been found on radiographic examination; this occurred in one of our cases. This difficulty of diagnosing fractures of the knee condyles by radiography has been pointed out by *Hirsch* (14) in a paper on experimental knee fractures.

How, then, shall injuries, especially those of the tibial collateral ligament, be diagnosed? The examination must be performed in the flexed position. In flexion of only a few degrees the posterior capsule can prevent marked lateral mobility. A flexion of 20° will relax the capsule enough to permit a considerable lateral mobility, and in this position the full range of lateral mobility permitted by severed collateral and cruciate ligaments will be obtained. If, on the other hand, the flexion is greater than this it will be increasingly difficult to restrict the movement to lateral mobility, and simultaneous rotation of the hip joint will easily result; this will complicate the assessment of the lateral instability.

With an angle of 160° there was an increase in lateral mobility as the two portions of the tibial collateral ligament and the cruciate ligaments were severed in turn, but this increase was strikingly moderate, and in spite of the fact that the two portions of the tibial collateral ligament and both cruciate ligaments were severed, the lateral mobility was sometimes as small as 6°. An examination of the damaged knee alone will therefore hardly suffice to show whether the lateral instability is normal or pathologic. To confirm the diagnosis a careful comparison between the two knees, and experience in such an examination, are necessary. The technique shown in Fig. 2 would seem to give the best results. The severance of both portions of the medial collateral ligament may sometimes result in such a small increase in lateral mobility that, (compared with the sound side), it will hardly be detectable at a clinical examination. A study of the rotational stability of the knee joint, to be published in due course, will show that by examining the rotation of the joint one can obtain a more accurate measure of the extent of damage to the two portions of the tibial collateral and the anterior cruciate ligaments.

SUMMARY

A clincal examination of some 50 knee-joints in patients and an experimental study of 16 knee joints from autopsy specimens has been performed. The relationship between the lateral instability of the knee joint and various injuries to the ligaments was especially investigated. It was concluded that lateral instability of the knee-joint in extension must be due to a loss of substance in the condyles of the knee owing to fracture or osteoarthritis, and that in other cases the knee in full extension is always stable in the lateral direction irrespective of how many of the ligaments are severed. This stability is due to the posterior articular capsule, which in extension presses the 4 condyles together and prevents any lateral mobility so long as extension is maintained.

In severe injuries in which the posterior capsule is also ruptured the knee becomes completely unstable.

The method commonly recommended for testing the ligaments of the knee-joint in extension is inaccurate.

RESUME

Un examen clinique de 50 articulations du genou de malades et une étude expérimentale de 16 articulations de genou provenant d'autopsies ont été accomplies. Les rapports entre l'instabilité latérale de l'articulation du genou et différentes lésions des ligaments ont été spécialement étudiés. Il est conclu que l'instabilité latérale de l'articulation du genou en extension doit être due à une perte de substance des condyles du genou provoquée par la fracture ou l'ostéoarthrite et que, dans les autres cas le genou en pleine extension est toujours stable en direction latérale, quel que soit le nombre des ligaments blessés. Cette stabilité est due à la capsule articulaire postérieure qui en position d'extension presse ensemble les quatre condyles et empêche toute mobilité latérale aussi longtemps que l'extension est maintenue.

Dans les lésions graves chez lesquelles il y a également rupture de la capsule postérieure, le genou devient entièrement instable.

La méthode recommandée communément pour mettre à l'épreuve les ligaments de l'articulation du genou en extension ne fournit pas des données exactes.

ZUSAMMENFASSUNG

Eine klinische Untersuchung an Kniegelenken von Patienten und eine experimentelle Studie an 16 Kniegelenken von Autopsiepräparaten wurde ausgeführt. Die Beziehung zwischen lateraler Instabilitet des Kniegelenkes und verschiedener Beschädigung der Ligamente wurde besonders untersucht. Die Schlussfolgerung war, dass laterale Instabilitet des Kniegelenkes bei voller Streckstellung ihre Ursache in einem Substanzverlust der Kondylen entweder wegen eines Bruches oder wegen Osteoarthritis haben muss, und dass in anderen Fällen das Knie bei voller Streckung in lateraler Richtung stets stabil ist, gleichgültig wie viele der Bänder getrennt sind. Die Stabilitet wird von der hinteren Gelenkskapsel besorgt, die die 4 Kondylen bei Streckstellung zusammenpresst und jede laterale Beweglichkeit verhindert, so lange die Streckung erhalten bleibt.

Bei schweren Schäden, bei denen auch die rückwartige Kapsel zerissen ist, wird das Knie vollständig unstabil.

Die im allgemeinen anbefohlene Methode der Prüfung der Knieligamente bei gestreckter Stellung ist unrichtig.

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