Effect of femoral condyle configuration on disability after an anterior cruciate ligament rupture

100 patients followed for 5 years

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We measured the configuration of the femoral condyles on lateral radiographs in 100 consecutive, prospectively-studied patients with a complete rupture of the anterior cruciate ligament, with or without associated lesions of the menisci and collateral ligaments. The patients had mainly low-to-moderate activity demands, and in all the patients the cruciate tear was primarily treated non-operatively. A quotient was calculated from the measurements of sagittal depth and axial height in order to describe the geometry of the femoral condyles. Measurements were reproducible with an intra- and interobserver coefficient of correlation of 0.89–0.98. At follow-up, after 5 (3–6) years, 16 patients had developed disability leading to reconstructive surgery. The remaining 84 patients did not have any major functional limitations, but some had reduced their activity level. Individual variations in the articular geometry were found with a more spherical shape of the femoral condyles in the patients where non-operative treatment had failed. Our findings indicate that articular geometry is of importance for function after an anterior ligament lesion.

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Differences in the configuration of the femoral condyles could affect the quality of the pivot shift subluxation phenomenon. A femoral condyle with a longer excursion sagittally would allow a more sliding motion, whereas a shorter condyle would lead to a more definite and rapid jerk, mainly against the convex lateral tibial condyle. A more spherical knee would also, for the same reason, be more vulnerable and easy to displace in weight-bearing activities, compared to a knee with a relatively longer condyle sagittally.

This might result in different demands on neuromuscular function to control the joint position in the absence of anterior cruciate function. In order to evaluate if there are radiographically measurable differences in the shape of the femoral condyles, we have compared patients with functional instability and recurrent giving way to patients without any significant impairment of function or giving way after a total anterior cruciate ligament rupture.

Patients

100 prospectively studied consecutive patients with an acute total anterior cruciate ligament rupture, with or without associated collateral ligament and meniscal lesions, were treated without any primary repair of the ligament injuries. The majority of patients were active in recreational sports or competed on a low to moderate level. Excluded from the study were patients with previous injuries to the lower extremities, radiographic skeletal lesions, age over 40 years and patients with psycho-social disorders. Athletes performing competitive contact sports who were not willing to reduce their activity level were also excluded and primarily treated surgically. All patients started a rehabilitation program immediately after an arthroscopic evaluation of the acutely injured joint, in which meniscal surgery, if necessary was performed. The patients were taught the significance of functional instability and recommended to avoid contact sports, jumping and cutting maneuvers, but were otherwise, after the rehabilitation program, allowed sporting activities. No derotational braces were used, but all patients were given a small elastic brace with metallic hinges for sporting activities. The patients were carefully monitored during the rehabilitation and follow-up periods.

The patients have been followed for a mean of 5 (3–6) years, and those with more than one substantial reinjury have been recommended a reconstruction of the anterior cruciate ligament. 16 patients have been

Table 1. Description of the operated (A) and non-operated (B) groups of patients. ***SD***

	Group A	Group B
Patients	16	83
Men	11	47
Age at injury (range)	26 (16–40)	25 (14–40)
Body weight (kg)	75 *12*	72 *14*
Body length (cm)	177 *6*	176 *9*

operated because of giving way, an unacceptable activity level, or a reinjury resulting in a symptomatic reparable meniscal lesion (Group A). Surgery was elected without knowledge of the radiographic measurements. The remaining 84 did not have any major disability but some have decreased their activity level (Group B). Only 1 patient is missing because the radiographs from the time of injury 5 years ago could not be found and the patient was no longer living in the region. Thus Group B consisted of 83 patients in this radiographic study (Table 1). There were no differences between the 2 patient groups regarding body weight, height and age.

Methods

The radiographic measurements were performed on non-weight-bearing, standard lateral radiographs as follows (Figure 1): a line (A) was drawn from the most distal point of the anterior angle of Blumensaats line (P 1) to the center of the femoral shaft 10 cm above the joint line (P 2). Perpendicular to this axial line, 2 additional lines were drawn to the most posterior point on each femoral condyle. The midpoint between these lines on line A was called P3 and the mean length of the lines was called X and represents the sagittal depth of the condyles.

The tangents of the most distal parts of each condyle, perpendicular to line A, were drawn and the midpoint between these lines on line A was called P 4. The distance P 3 to P 4 represents the height of the condyles, which was called Y.

A quotient Z was determined by dividing the condyle height (Y) by the sagittal depth (X). This quotient describes the relation between height and depth, without any error from small differences in magnification between the individual radiographs (Figure 2). Radiographs showing more than 10 mm distance between the medial and lateral condyle contours were excluded and new films obtained. Measurements were performed without prior knowledge of the treatment group. To determine the intra- and interobserver variations of the measuring technique, Group A was measured twice by a radiologist and the first measurement was compared to measurements made by a second radiologist. Although we have used the mean value of the medial and lateral condyles, the midpoint of the femoral shaft and the Blumensaats line, all centrally located, the effect of rotational differences between the radiographs could not be neglected. Therefore, 12

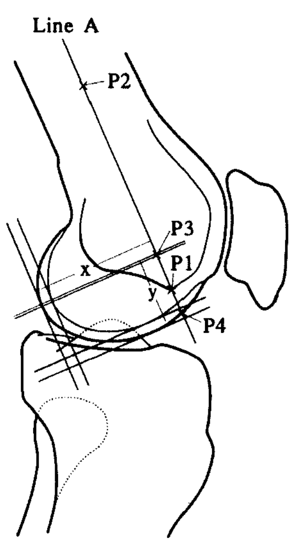

Figure 1. The method used to measure the geometry of the femoral condyles on lateral radiographs, as described in text.

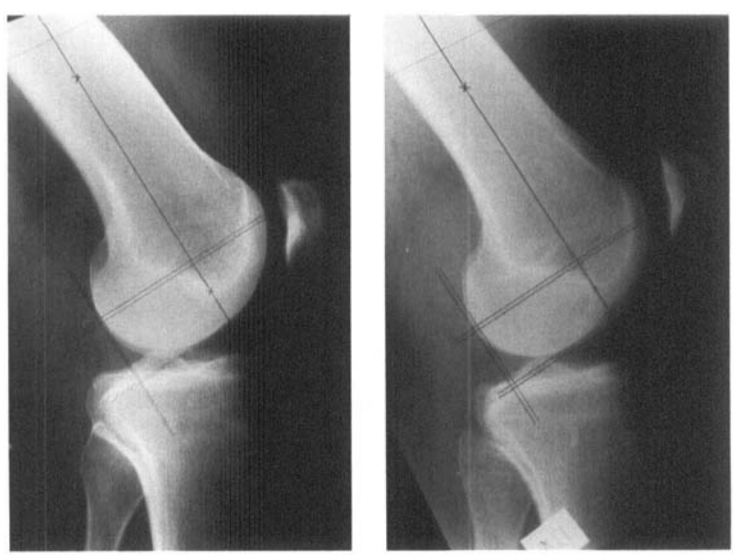

Figure 2. A knee with a more spherical configuration (left; condyle quotient 0.64), as compared to a knee with a relatively larger sagittal depth (right; condyle quotient 0.51).

measurements were made on straight lateral radiographs and compared with measurements from the same knees exposed in both internal and external rotation where the condyle contours on the radiographs were separated approximately 10 mm.

Statistics

The coefficient of correlation was used to assess reproducibility between measurements. Paired and unpaired Student's *t*-tests were used in comparisons between groups.

Results

When the repeated radiographs with small differences in rotation were measured, we found no difference between the straight lateral, internally or externally rotated radiographs. The mean qoutient was 0.58 *SD 0.04* in all 3 rotational positions. Repeated measurements of sagittal depth (X) and height (Y) by the same radiologist showed coefficients of correlation of 0.89 and 0.95, respectively. The corresponding interobserver correlation was 0.98 and 0.96. The 16 patients in Group A, operated on with a ligament reconstruction, had a mean quotient of 0.61 *0.04* and Group B, without any major functional limitations 0.57 *0.04* (*P* 0.002).

Discussion

Motion characteristics of the knee depend on mechanical and structural interrelations between the articular surfaces, the ligaments, menisci, loading conditions and muscle activity. Mathematical knee-modeling has mainly described passive motion characteristics, depending on articular surface geometry related to tension and strain in the ligaments. This mathematical model was found to be improved if based on characteristics of an individual knee with its specific articular and ligamentous anatomy (Blankevoort 1991). The anterior ligament has a crucial role in maintaining joint congruity, mainly by preventing the tibia from anterior displacement. A medial transformation of the axis of rotation after rupture of this ligament leads to an anterior translation of both tibial condyles when a pivot-shift test is performed (Noyes et al. 1989, Reuben et al. 1989, Matsamuto 1990). Matsumoto (1990) found that only 7 out of 20 cadaver knees had a pivot shift classified as a sudden jerk after sectioning the anterior ligament, when the same rotational and valgus forces were applied to all specimens. The finding of no pivot shift or a more gradual reduction was suggested to depend on differences in the convexity of the lateral tibial condyle, but no measurements were presented. Noyes and Grood (1988) ascribed this qualitative difference in the pivot shift phenomenon to individual variations in laxity of the secondary restraints.

To our knowledge, only one study has investigated a possible relationship between the skeletal configuration of the individual knee and the development of symptoms after an anterior ligament rupture (Kujala et al. 1992). The lever arm and forces acting on the ligament-deficient knee are related to the length of the limb and body-weight. This is important, since giving way is a phenomenon occurring in a standing weight-bearing position. Mensch and Amstutz (1975) measured several dimensions of cadaveric knees and also on radiographs. They found the male knee to be, on average, 12 percent larger than the female knee and also some differences in the relative size of the femoral condyles. Males tended to have a greater sagittal depth of the medial condyle, and females a greater sagittal depth laterally, when the femuropatellar part of the condyle was included. A consistent correlation between the dimensions of the knee and the patient's body height was observed, but no correlation to body weight.

We found no differences in body weight or height between our patient groups, and there was no difference in the configuration of the measured part of the femoral condyles between the sexes. We measured the femoral condyles, focusing on the femuro-tibial contact area in a standing weight-bearing position, deliberately avoiding the patello-femoral articulation as well as the contact area between the femur and the tibia in a more flexed position.

In the study by Mensch and Amstutz (1975), a dimensional relationship between the measured parameters of the knee and the total width of the femur was found. The coefficient of correlation varied among the parameters and when the anterior radius of each femoral condyle (estimated to include the femorotibial contact area at 0–45 degrees of flexion) was related to the total width of the femur, a lower coefficient of correlation than an average of the other dimensions was found, indicating individual variations in the geometrical spherical shape of both the medial and lateral femoral condyles. We have chosen to describe the shape of the condyles by dividing the height of the condyles by the depth rather than by measuring the anterior radius, in order to avoid an error from small uncontrolled differences in magnification between the individual radiographs and to avoid errors from difficulties in identifying landmarks limiting the measured sector of each condyle.

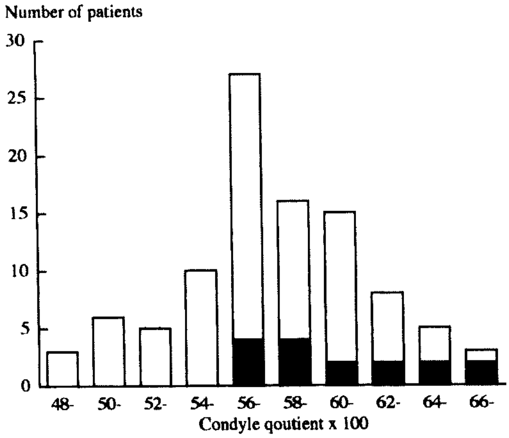

Figure 3. The frequency distribution of the calculated quotient describing the configuration of the femoral condyles in a group of 99 consecutive patients with a total anterior cruciate ligament rupture. Black indicates the patients where disability led to a ligament reconstruction.

Hefzy et al. (1989) used the intersection of the trochlear groove with the roof of the intercondylar notch as a reference point for the description of femoral condyle geometry in cadaveric specimens. On radiographs, this point corresponds to the anterior angulation of Blumensaats line.

Our major landmark is the most distal point on the anterior angulation of Blumensaats line, and once this point has been chosen the rest of the measuring points are easy to identify, which is proved by the high intra- and interobserver coefficient of correlation. The measurements followed a normal distribution which represents an accurate determination of a biological variation (Figure 3). Another possible effect from the differences in the sagittal configuration of the femoral condyles is a variation in effect of muscle contractions on the joint. The force vector of the hamstrings and the gastrocnemius and its relation to the transverse rotational axis of the knee might vary, thereby affecting the amount of posteriorly-directed force on the tibia during a muscle contraction.

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