RADIOGRAPHIC ANALYSIS OF PATELLAR TILT

RONALD P. GRELSAMER, ANDREW N. BAZOS, CHRISTOPHER S. PROCTOR

From the Columbia-Presbyterian Center for Sports Medicine, New York, USA

We describe the radiographic measurement of the angle of tilt of the patella and relate it to malalignment of the extensor mechanism. The tilt angle is defined as the angle subtended by a line joining the medial and lateral edges of the patella and the horizontal. The radiograph (Merchant type) is taken with the foot pointing up, the lower edge of the film parallel to the ground, and the knee at 30° flexion. The mean tilt angle of a group of patients with signs and symptoms suggesting patellofemoral malalignment was 12° (± 6°); in a similar group of control subjects it was 2° (± 2°) (p < 0.01). Tilting of 5° was taken to be the limit of normal. For the detection of patellar malalignment, the tilt angle was almost as specific as the congruence angle (92% v 99%) but more sensitive (85% v 25%) and more accurate (89% v 62%).

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Gross malalignment syndromes and dislocations of the patella are easily diagnosed, but more subtle malalignment and patellar tracking disorders often escape detection. The congruence angle was described by Merchant et al (1974) and used by others (Aglietti, Insall and Cerulli 1983; Hughston, Walsh and Puddu 1984; Fulkerson et al 1987; Inoue et al 1988; Scuderi, Cuomo and Scott 1988). Although it is highly specific, it is not sensitive enough to detect minor degrees of malalignment. Inoue et al (1988) found that only 30% of patients with clinical patellar subluxation had an abnormal congruence angle.

Many ratios and indices reflecting structural variations of the extensor mechanism in the coronal plane have been described (Wiberg 1941; Brattström 1964; Merchant et al 1974; Cross and Waldrop 1975; Laurin et al 1978; Sasaki and Yagi 1986; Fulkerson et al 1987; Inoue et al 1988; Kujala et al 1989). The earlier studies involved the anatomy of the trochlea and the patella (Wiberg 1941; Brattström 1964) but more recent papers have focused on the position of the patella with respect to the trochlea (Sasaki and Yagi 1986; Schutzer, Ramsby and Fulkerson 1986; Fulkerson et al 1987; Inoue et al 1988; Kujala et al 1989; Koskinen, Hurme and Kujala 1991). To avoid the distortion of leg rotation, various landmarks on the femur were chosen as reference points, including the trochlea, the anterior aspect of the femoral condyles and more recently, with the advent of CT and MRI, the posterior femoral condyles (Schutzer et al 1986; Fulkerson et al 1987; Inoue et al 1988).

The detection of lateral displacement was the sole purpose of these patellar indices until Laurin et al (1978) introduced the concept of patellar tilt as a form of malalignment. This tilt could be observed even with the patella completely reduced in the femoral groove and was therefore independent of the mediolateral position of the patella. The lateral patellofemoral angle which they described is thus more a measure of tilt than of displacement. The patella, however, needs to be severely tilted before the lateral patellofemoral angle becomes abnormal, and the method cannot detect minor degrees of tilt. The patients who formed the basis for the study of Laurin et al had such severe malalignment that they were already scheduled for surgical treatment.

Other tilt angles have since been introduced and measured on plain radiography, CT or MRI, including those of Sasaki and Yagi (1986), Fulkerson et al (1987), Inoue et al (1988) and Kujala et al (1989). Despite their several advantages, we have found the techniques to be expensive and/or difficult to use for routine screening.

We sought a simple and reproducible measure of patellar tilt from conventional (Merchant-type) radiographs.

MATERIALS AND METHODS

Axial radiographs of 100 consecutive patients with signs and symptoms suggesting patellar malalignment (group I) were examined and compared with similar views of 100 consecutive patients with knee findings which did not suggest patellar pathology (group II, control group). Patients with tricompartmental osteoarthritis or inflammatory arthritis were excluded from the study. Two patients in group I and three in group II had palpable effusions. Of the many (controversial) signs and symptoms of patellar malalignment described in the literature we have used the following: a documented history of dislocation; visible lateral subluxation as the knee is...
extended passively or actively; palpable patellar tilt with medial or lateral facet/retinacular tenderness; a positive apprehension (Fairbanks) test; and/or anterior knee pain after prolonged sitting. All patients were examined by the senior author (RPG).

Radiographs were taken as described by Merchant et al (1974) except that the knee was flexed to 30° not 45°. Care was taken to keep the axis of the patient’s forefoot vertical (foot progression angle 0°). To establish the horizontal, the lower edge of the X-ray cassette was held parallel to the ground by a commercially available cassette holder (Fig. 1).

Tilt was assessed by drawing a line from one corner of the patella to the other (Fig. 2) and was measured as the deviation of this line from the horizontal (the lower edge of the radiograph). Lateral tilt was termed 'positive' to correlate with similar measurements described in the literature on the biomechanics of the patella (Veress et al 1979; van Kampen and Huiskes 1990; Hirokawa 1991).

When the two edges of the patella were not readily visible, a line was drawn along the anterior cortex of the patella which is parallel to the edge-to-edge line.

The congruence angle was measured in all subjects by the method described by Merchant et al (1974).

RESULTS
Statistical analysis of the demographics of the two groups with respect to gender and age revealed no significant differences.

The mean tilt angle for group I was 12° ± 6° and for group II, 2° ± 1° (p < 0.01). A tilt angle of more than 5° was found in 85 of group I; an angle of 5° or less was found in 92 of group II (Fig. 3). Patellar tilt greater than 5° was therefore 85% sensitive and 92% specific in detecting patellofemoral malalignment and the overall accuracy of the patellar tilt test was 89%.

The congruence angle was normal in 99 of group II but was abnormal in only 25 of group I, an accuracy of only 62%.

We found that a tilt angle of about 20° was required for a patella to have an abnormal patellofemoral angle (Laurin et al 1978). This test was positive in only seven patients in group I and none in group II (7% sensitivity, 100% specificity).

DISCUSSION
Severe malalignment of the extensor mechanism requires no special radiological index for diagnosis but more subtle, although none the less disabling, conditions need to be demonstrated radiographically. The numerous indices which have been described can be grouped according to the feature of the patella which is used and

Figure 3a – Example of a normal tilt angle (< 5°) in a control patient. Figure 3b – Example of an abnormal tilt angle (15°) in a patient with symptomatic patellar malalignment.
the reference point on the femur from which it is measured. The angle of a line connecting the bottom of the trochlear groove to the lowest point of the patella (e.g., congruence angle) can determine the mediolateral position of the patella but is insensitive to tilt. The lack of sensitivity of the congruence angle has been reported previously (Inoue et al 1988) and was confirmed in our study.

The radiological feature measured for Laurin's patellofemoral angle is the slope of the lateral patellar facet; it has also been used in CT imaging (Schutzer et al 1986; Shellock et al 1989). The shape of the lateral facet of a given patella is, however, dependent on the Wiberg (1941) classification of patellar shape, and its slope may vary between patients independently of the degree of tilt. More significantly, the slope of the lateral facet does not relate to the clinical assessment of tilt which is appreciated from palpation of the edges of the patella.

The use of a line connecting the two edges of the patella has a number of advantages: it is independent of patellar morphology; it is usually easy to draw on the radiograph and, when it is not, a line parallel to the subchondral bone of the anterior patella will suffice; it has been used to measure tilt in some recent biomechanical studies of patellar tracking (Veress et al 1979; van Kampen and Huiskes 1990; Hirokawa 1991); and it corresponds to the clinical evaluation of tilt. It was used by Sasaki and Yagi (1986), Kujala et al 1989, and Koskinen et al (1991).

On the trochlear side, the line connecting the anterior margins of the condyles, used by Laurin et al (1978), Koskinen et al (1991) and Sasaki and Yagi (1986), varies with the patient's morphology, particularly that of the distal femur (Fulkerson et al 1987). Dysplasia of one condyle, a common finding in malalignment, may lead to over- or underestimation of tilt. The posterior margins of the condyles are not subject to dysplasia to the same extent, but the position of one condyle relative to the other varies with the level of section (Koskinen et al 1991). In addition, femoral torsion can cause rotation of the distal femur and CT and MR imaging are too expensive to use for routine screening.

Our use of the horizontal as a reference line is a significant departure from existing indices. As it is not a feature of the anatomy the angle measured may vary with leg rotation. The dependence of the tilt angle on leg rotation is a considerable drawback, but one which the lower accuracy and higher cost of indices that try to be independent of leg rotation makes us willing to accept.

The prevalence of patellar tilt in the absence of subluxation and vice versa is open to discussion. Schutzer et al (1986) found that only 19 of 45 patients had tilt without subluxation with the knee at neutral extension. In our study, carried out at 30° flexion, 75% of patients had tilt without subluxation and only 2% had subluxation without tilt. At 30° flexion, the trochlea constrains the patella to normal mediolateral alignment but tilt is still present (Kujala et al 1989; Grelsamer and Cartier 1990; Hirokawa 1991; Koskinen et al 1991). This masking of lateral subluxation in flexion tends to heighten the importance of an index which detects tilt rather than subluxation.

The 85% accuracy of our tilt angle is considerably better than that of the congruence angle as reported by us and by others (Aglietti et al 1983; Inoue et al 1988). The method can be easily and inexpensively used in the routine clinical investigation of patients with anterior knee pain.

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REFERENCES


