Patellar alignment evaluated by MRI

Thomas Muellner[1], Martin Funovics[2], Ajsa Nikolic[1], Victor Metz[2], Rudolf Schabus[1] and Vilmos Vécsei[1]

We analyzed the congruence of the articular cartilage surfaces and the corresponding subchondral bone in the patellar joint. 20 volunteers underwent MRI investigations of the right patellar joint in 20° and 45° flexion in the axial plane. The sulcus, congruence, and lateral patellofemoral angles, measured on MRI slices centered through the midtransverse patella, were recorded. In 20° and 45° knee flexion, the bony sulcus and lateral patellofemoral angles were significantly different from the respective cartilagineous angle. We conclude that 1) measurement of the bony sulcus and lateral patellofemoral angles does not allow conclusions about the articular cartilage surface and its thickness, 2) the bony congruence angle corresponds well to the articular cartilage surface as an indicator of patellar centralization.

[1]University Clinic of Traumatology, [2]Clinic of Radiodiagnostics, Surgical Division, University of Vienna Medical School, Waehringerguertel 18-20, AT-1090 Vienna, Austria. Tel +43 1 40400-5619. Fax -5949. E-mail: tmuellner@csi.com
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Subtle malalignments of the patellar joint are often difficult to diagnose, whereas severe malalignment syndromes and dislocations of the patella are more easily detected (Post 1997). While earlier studies involved the anatomy of the femoral trochlea and the patella (Wiberg 1941, Brattström 1964), more recent studies have focused on the position of the patella, using radiograms (Merchant et al. 1974, Laurin et al. 1978, 1979) or CT (Fulkerson et al. 1987, Inoue et al. 1988). Some studies focused on the patellar tilt (Laurin et al. 1978, 1979, Grelsamer et al. 1993), while others involved the congruence angle (Merchant et al. 1974, Aglietti et al. 1983, Fulkerson et al. 1987, Inoue et al. 1988). Sensitivities of 30% for the congruence angle (Inoue et al. 1988), and 85% for the modified lateral patellofemoral angle, as described by Grelsamer et al. (1993), were found in detecting patellofemoral malalignment.

Radiographic studies allow only measurements or descriptions of the bony patellofemoral joint. The articular cartilage surfaces have not been considered in previous reports. We tried therefore to analyze the congruence of the articular cartilage surfaces and the corresponding subchondral bone of the patellofemoral joint in the axial plane, using magnetic resonance imaging (MRI).

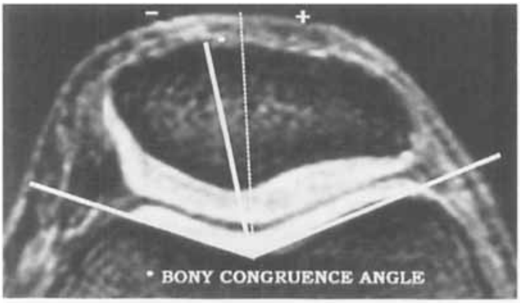
Subjects and methods

20 healthy volunteers (14 men), with no history or physical signs of patellar problems or knee operations, were investigated. The mean age was 28 (21–37) years. The length of the patella and the patellar tendon were measured on lateral radiographs, taken in supine position, with the knee flexed to 60°, as described by Insall and Salvati (1971). The patellar height was then calculated by dividing the length of the patellar tendon by the length of the patella.

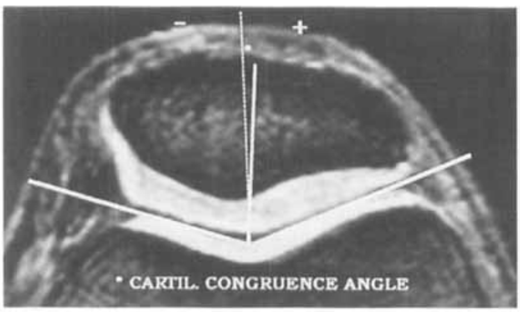
The MRI investigation was performed on a Siemens Magnetom Vision 1.5 Tesla unit with an extremity coil. A cartilage-sensitive Flash 3D sequence was employed, with a flip angle of 60°, which allowed a precise distinction between the subchondral bone and the articular cartilage. Repetition time and echo time were 60ms and 11ms, respectively. The patellar joint was imaged in the axial plane, using slice thickness set to 1.5 mm in a field of view of 120 × 160 mm and a matrix 144 × 256 pixels. Data were obtained with the knee flexed to 20° and 45°. The flexion angle was controlled with a hand-held goniometer. In order to avoid flexion angle variations during the MRI investigation, custom-made foamed plastics molds were used to fix the knee at the prespecified angle. The slice, centered on the midtransverse patella and perpendicular related to the patella, was selected and magnified 3 times to define the patellar position more accurately. In 20° knee flexion, the cartilage on the highest points of the medial and lateral condyles is so thin that an accurate distinction between cartilage and bone was not possible. The line drawn across the bony and cartilaginous femoral condyles was therefore defined as the same.

The bony patella was described according to

Figure 1. The congruence angle.

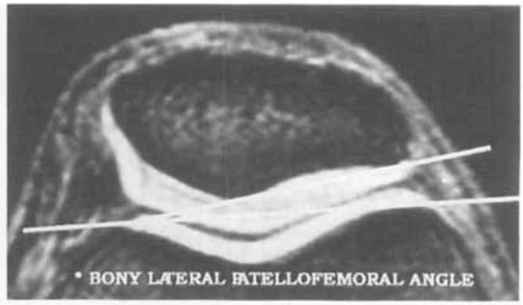


A. The congruence angle is determined by bisecting the sulcus angle (dotted line), and projecting a second line from the apex of the sulcus to the lowest point of the patellar ridge (full line); the angle is formed between this line and the bisecting line (45° of knee flexion).

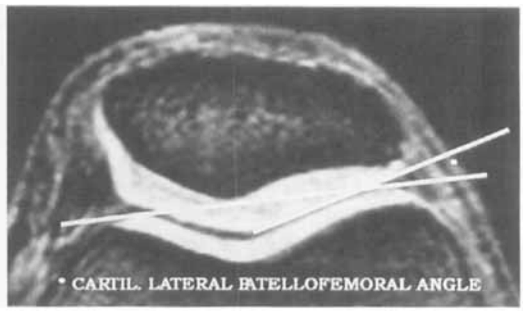


B. The congruence angle is shown when using the articular cartilage surfaces (45° of knee flexion).

Figure 2. The lateral patellofemoral angle.



A. The lateral patellofemoral angle is the angle between the anterior tangent of the femoral condyles and the tangent of the lateral patellar facet (45° of knee flexion).



B. The lateral patellofemoral angle is shown when using the articular cartilage surfaces (45° of knee flexion).

Wiberg's (1941) classification and the patella index was recorded as described by Cross and Waldrop (1976). The following angles were calculated for both the subchondral bone and the articular cartilage surfaces. The sulcus and the congruence angles were recorded as described by Merchant et al. (1974) (Figure 1). The lateral patellofemoral angle was measured as described by Laurin et al. (1978) (Figure 2). Two radiologists (MF, VM) made the measurements independently and the interobserver variability was determined using the Pearson correlation coefficient. The limits of agreement were calculated as described by Bland and Altman (1986). The recorded angles were compared using an analysis of variance with repeated measurements and an unstructured variance-covariance matrix (SAS/STAT User's Guide 1990). A p-value of less than 0.05 was considered statistically significant.

Results

The right knee was investigated in all volunteers. The mean Insall-Savati ratio was 1.06 (SD 0.11). According to Wiberg's classification, 3 patellae were classified as type I, 15 as type II, and 2 patellae were classified as type III. A mean patella index of 8.8 (SD 4.8) was recorded.

In 20° of knee flexion only the bony sulcus angle and the bony lateral patellofemoral angles were significantly different when compared to the respective angle derived from the articular cartilage surfaces (Table). The mean lateral patellofemoral angle was 8.4° (SD 0.9) for the subchondral bone, and 9.4° (SD 1.2) for the articular cartilage surface ($p = 0.01$). The mean sulcus angle was 139° (SD 1.7) for the subchondral bone and 148° (SD 2.8) for the articular cartilage surface ($p = 0.01$). The mean congruence angle was –5.9° (SD 3.5) for the subchondral bone and –7.4° (SD 4.4) for the articular cartilage surface ($p = 0.3$).

In 45° of knee flexion both the bony sulcus angle and the bony lateral patellofemoral angle were significantly different from the respective angles derived from the articular cartilage surfaces (Table). The mean lateral patellofemoral angle was 10.3° (SD 1.0) for the subchondral bone, and 13.4° (SD 1.1) for the articular cartilage surface ($p = 0.005$). The mean sul-

The respective angles were measured in 20° and 45° knee flexion and recorded for both the subchondral bone and the articular cartilage surfaces, mean (SD)

Knee flexion angle	Bone	Cartilage	P-value
Sulcus angle			
20°	139° (1.7)	148° (2.8)	0.01
45°	132° (1.5)	145° (2.3)	0.0001
P-value	0.004	0.01	
Congruence angle			
20°	–5.9° (3.5)	–7.4° (4.4)	0.3
45°	–13.3° (3.4)	–19.1° (4.1)	0.7
P-value	0.01	0.006	
Lateral patellofemoral angle			
20°	8.4° (0.9)	9.4° (1.2)	0.01
45°	10.3° (1.0)	13.4° (1.1)	0.005
P-value	0.01	0.006	

cus angle was 132° (SD 1.5) for the subchondral bone and 145° (SD 2.3) for the articular cartilage surface ($p = 0.0001$). The mean congruence angle was –13.3° (SD 3.4) for the subchondral bone and –19.1° (SD 4.1) for the articular cartilage surface ($p = 0.7$). When comparing the angles derived from the two positions of knee flexion, significant differences were found for all three angles.

In an inter-observer study, the Pearson correlation coefficients for the bony angles were: sulcus angle 0.94, congruence angle 0.98, lateral patellofemoral angle 0.93. For the cartilage surface, the respective Pearson correlation coefficients were 0.83, 0.99 and 0.81. The calculated correlation was significant at the 0.01 level. The limits of agreement (mean difference, 2SD) for the respective angles were sulcus angle: bone 0.1, 3.8; cartilage 0.1, 4.4, congruence angle: bone 0.2, 3.8; cartilage 0.2, 5, lateral patellofemoral angle: bone: 0.9, 2.8; cartilage: 0.3, 2.7.

Discussion

Our purpose was to investigate whether the measurement of the bony patellar alignment correlates with measurements based on the articular cartilage surfaces. Previous radiographic methods, ratios, angles, and indices were all based on the subchondral bone (Wiberg 1941, Brattström 1964, Merchant et al. 1974, Laurin et al. 1978, 1979, Fulkerson et al. 1987, Inoue et al. 1988, Grelsamer et al. 1993). CT, when introduced to image patellar tracking, improved the accuracy and sensitivity of standard radiographs (Inoue et al. 1988, Stanciu et al. 1994). However, Stäubli et al. (1997) confirmed, in a combined cryosectional and MRI study, that the subchondral bone, as seen on CT scans, is not in accordance with the articular cartilage surface, as proposed by Wiberg (1941).

Our volunteers were all free of patellar problems. The measurements revealed no patellar or trochlear abnormalities with a normal patellar height. The MRIs were performed in 20° and 45° knee flexion to provide information about the early patellar route (entrance into the sulcus).

The bony sulcus angle in our study was in accordance with previously published values (Brattström 1964, Merchant et al. 1974). The bony sulcus angle was significantly smaller than the articular cartilage surface. The thickness of the cartilage and therefore the increase in the sulcus angle varied among the volunteers. Using the bony sulcus angle, no prediction could be made with regard to the thickness of the cartilage and the shape of the cartilage surfaces.

In all volunteers, the lateral patellofemoral angle was open laterally, which has been found to be normal (Laurin et al. 1978). The lateral patellofemoral angle showed a significant increase, when related to the cartilage, and between 20° and 45° knee flexion.

The bony congruence angle was comparable to the values given by Merchant et al. (1974). As compared to 20° of knee flexion, the bony congruence angle was more negative at 45° knee flexion, which was interpreted as a medial movement of the patella with increasing flexion, as described by Hefzy and Yang (1993), and Stein et al. (1993).

We found no systematic difference and no correlation factor between the values of the subchondral bone and the articular cartilage surface in all measured angles. Therefore the thickness and the shape of the articular cartilage could not be predicted by measuring angles derived from the subchondral bone. Although the lowest point of the articular surface of the patella is not a point but a curved line, the interobserver variability was low. Therefore, MRI of the patellar joint seems to allow a high reproducibility beween different observers.

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