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The patellotrochlear index: a new index for assessing patellar height

Received: 8 March 2005
Accepted: 25 May 2005
Published online: 23 February 2006
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Abstract The radiological methods to determine patellar height described in the literature are variable, not reliable and depend on the chosen ratio. The purpose of this paper is to describe another method of measuring patellar height on sagittal MRI using the true articular cartilage patellotrochlear relationship. An analysis of magnetic resonance (MR) examinations of 66 consecutive patients was performed. The most common diagnoses were meniscal or anterior cruciate ligament pathologies. No patient suffered from patellofemoral complaints. Measurements on sagittal MR images included different parameters using the articular cartilage of the patella and the trochlea. The ratio patella : trochlea of the cartilage baselines was measured in percentages and described as patellotrochlear index. The measurements were assessed at two different times by three raters under blinded conditions. The mean patellotrochlear

index was 31.7% (CI: 12.5–50.0; range –5.0 to 61.1%; SD ± 11.6). The intraobserver variability showed only in the “second observer” a difference of the mean values of the two different measurements ($t=2.189$; $P=0.032$). The interobserver correlation was high and significant (0.663–0.893; $P=0.000$). Our results indicate that the patellotrochlear index is a reliable and precise method to determine the exact articular correlation of the patellofemoral joint and the patellar height. The results represent the average patellotrochlear index in the normal population without patellofemoral complaints. Measurements of the articular cartilage congruence can be helpful to define an underlying pathology of patellar height, such as patella alta or infera.

Keywords Patellar height · Measurement · MRI · Articular cartilage · Patellofemoral

Introduction

The term patella alta is commonly used in the literature [2, 7, 18, 21, 22, 23, 25, 29, 31]. It is mentioned with regard to patellar instability [10, 12, 19, 20, 26, 27, 32], pain [2, 11, 15, 17, 31], chondromalacia [18, 22], gonarthrosis [1, 24], ossifications in the patellar tendon [8], and adolescent growth spurt [23]. Therefore patella alta is considered a relevant pathologic factor in patellofemoral disorders. Currently, the definition of patella alta

is insufficient and not clear [18, 21], although numerous methods to measure patellar height have been described [3, 5, 9, 13, 16]. Seil et al. [28] showed that patellar height classification and patella alta depend heavily on the chosen ratio. The differing results were mainly due to the anatomical (bony) differences [28].

The methods to determine patella alta or, in general patellar height, described in the literature are not reliable [21, 28]. In reality these methods measure the length of the patellar tendon to the longest sagittal diameter of the

patella ratio (Insall and Salvati [16]), the length of the patellar tendon to the length of the articular surface of the patella (Grelsamer et al. [14]), the length of the articular surface of the patella to the height of the lower pole of the articular surface above a tibial plateau line (Blackburne and Peel [5]), the distance between the distal point of the patellar articular surface and the anterosuperior border of the tibia divided by the length of the articular surface of the patella (Caton et al. [9]), and the distance between the superior line of the trochlea and the inferior edge of the articular surface of the patella (Bernageau et al. [3]). All these different measuring methods use lateral radiographs to determine patellar height where the articular cartilage is not visible. Bosshard et al. [6] showed that there is a significant difference in the articular cartilage joint geometry and the corresponding subchondral osseous anatomy of the patella, and the femoral trochlea [30]. This means that all ratios using radiographs do not measure the real articular congruence between patella and distal femur but measure ratios given by different and variable osseous landmarks.

We think that the only ratio that is accurate for the determination of patellar height and for all patients who are present with a clinical disorder and some complaint about patellofemoral pain is the ratio between the articular cartilage of the patella and the trochlear cartilage. This study aimed (1) to determine the patellotrochlear articular cartilage ratio (2) in a normal population, to define patella alta, normal, and patella infera, and (3) to present this patellotrochlear index as another method to measure patellar height.

Materials and methods

Patients

We analyzed the MR examinations of sixty-six consecutive patients. Most of the patients had meniscal or anterior cruciate ligament pathologies. No patient suffered from patellofemoral complaints, neither anamnestic nor during the physical examination.

MR measurements

MR examinations were performed using a Magnetom Impact 1.0 Tesla (Siemens) with the knees in 0° of flexion, the foot in 15° external rotation, and the quadriceps muscle consciously relaxed. Measurements on sagittal MR images included different parameters [4] (Figs. 1, 2): (1) Baseline patella (BL_P); (2) Baseline trochlea (BL_T); (3) Ratio BL_P:BL_T. The parameters were measured on the midline sagittal section MRI through the patella with the thickest articular cartilage and maximal length

of the patellar bone. The patellotrochlear index was calculated as the Baseline patella (BL_P):Baseline trochlea (BL_T) ratio measured in percentages.

The measurements on the MR images were assessed independently at two different times (more than a six-week interval) by three raters (the two authors and another orthopaedic surgeon) who were blinded to the patients' data.

Statistical analysis

For statistical analysis we used the total index in percentages. Paired samples *t* test was performed to examine intraobserver variability. Spearman's rank correlation was calculated to determine the interobserver correlation. To determine "normal values" of the patellotrochlear index we used the 95% confidence interval (lower/upper bound). A *P* value of 0.05 was considered to be significant. Statistical analysis was performed with Statistical Package of Social Sciences (SPSS).

Results

The sixty-six patients (forty-four males, twenty-two females) had an average age of 38.2 years (range, 12–36 years). The mean patellotrochlear ratio was 31.7% (CI: 12.5–50.0; range –5.0 to 61.1%; SD ± 11.6). The paired samples *t* test showed only in the "second observer" a difference of the mean values of the two different measurements (*t* = 2.189; *P* = 0.032). The interobserver correlation was high and significant (0.663–0.893; *P* = 0.000).

Discussion

Standard radiographs document only the osseous contours of the patellofemoral joint and the position of the patella in reference to the trochlea. Thickness and condition of the articular cartilage can only be measured using MRI or MR arthroto-mography. Bosshard et al. [6] found no contour congruence of articular cartilage surface and subchondral bone of the patellofemoral joint both in the sagittal and axial plane. Our study confirms the significant cartilage-bone mismatch in the sagittal plane of the patellofemoral joint. The osseous anatomy in the sagittal plane of the patellofemoral joint does not correspond with the articular cartilage surface. We agree with Seil et al. [28] that the most important factor in patellar height determination is the position of the articular surface of the patella in relation to the trochlear cartilage (Fig. 3a, b). Statements about patella alta or infera, using only standard radiographs, must therefore be interpreted with caution and awareness of this fact.

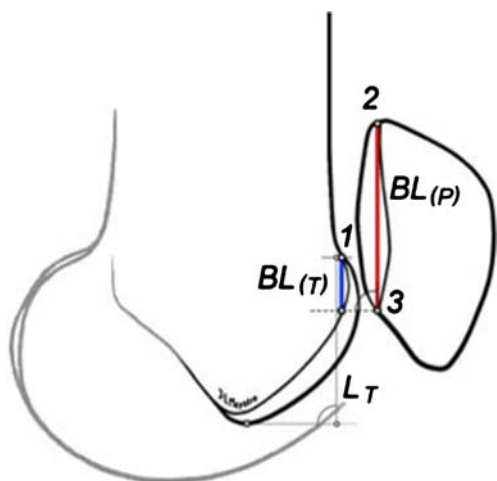


Fig. 1 Patellochlear index measurement⁴: BL_P Baseline patella (2 superior most aspect of articular cartilage to 3 inferior most aspect); BL_T : Baseline trochlea (length of trochlear articular surface from 1 superior most aspect with respect to 3 the inferior most aspect of the articular patellar cartilage using a right angle and parallel lines); *Ratio* BL_T / BL_P calculated in percentages; L_T Length of trochlear cartilage (superior most aspect to inferior most aspect of trochlea using a vertical line)

With regard to the statistical analysis (95% confidence interval; lower/upper bound), we think that index values of more than 50% document patella infera and less than 12.5% document patella alta.

The described patellochlear index measured on sagittal MR images is a reliable and reproducible

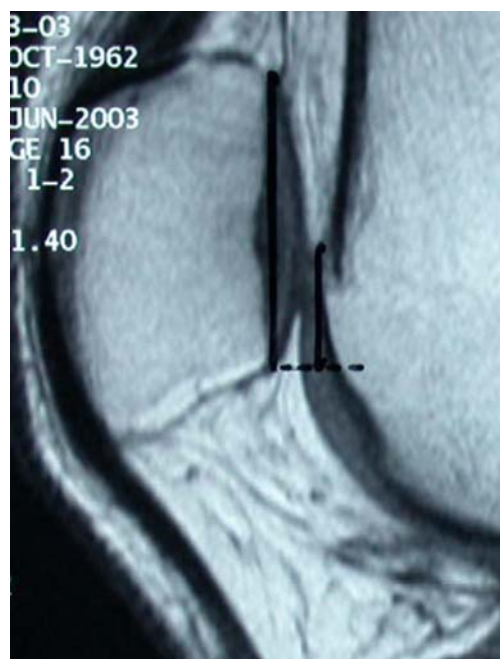


Fig. 2 Measurement of the patellochlear index on sagittal MRI



Fig. 3 a Sagittal radiograph showing normal radiological patellar height ratios measured according to Blackburne-Peel [5], Insall-Salvati [16], Grelsamer [13], Caton-Deschamps [9]. **b** MR measurement of the same patient showing no contact of the patellar and trochlear articular cartilage. The patellochlear index is 0% documenting patella alta

method to determine the exact articular correlation of the patellofemoral joint and the patellar height. The results of our study showed that the inter-and intraobserver variability is low which was confirmed by low mean standard errors and high correlation coefficients.

The major advantages of this index are: (1) exact measurement of the patellochlear articular congruence; (2) osseous form variations of the patella (i.e. long,



Fig. 4 Sagittal MR shows long and flat trochlea, long sagittal osseous diameter of the patella (nose) with relatively short articular cartilage



Fig. 5 Sagittal MR shows short trochlea and relatively short osseous sagittal diameter of the patella compared to the articular cartilage

nonarticular inferior pole) [14] do not affect the ratio (Figs. 4, 5), (3) differences of length and shape of the trochlea are considered; (4) variations of the patellar tendon attachment areas are insignificant (Sinding-Larson-Johansson or Osgood-Schlatter disease; after surgical interventions); (5) thicker radiolucent cartilage in children is visible; (6) no ionizing radiation exposure, and (7) measurements in 0° knee flexion is easier than in 30° of flexion.

In contrast to Miller et al. [25], we did not measure the trochlear articular length using the distal femoral physal scar. Our evaluation of the MRI examination documented that this point of reference lays frequently more proximal than the end of the trochlear cartilage, shows variations, and is therefore not as precise as our described method (Fig. 6a, b). In our opinion, the most superior aspect of the trochlear articular surface can be determined easier and more precisely than the distal femoral physal scar. In addition, the articular cartilage provides more evidence for the articular congruence than the physal scar.

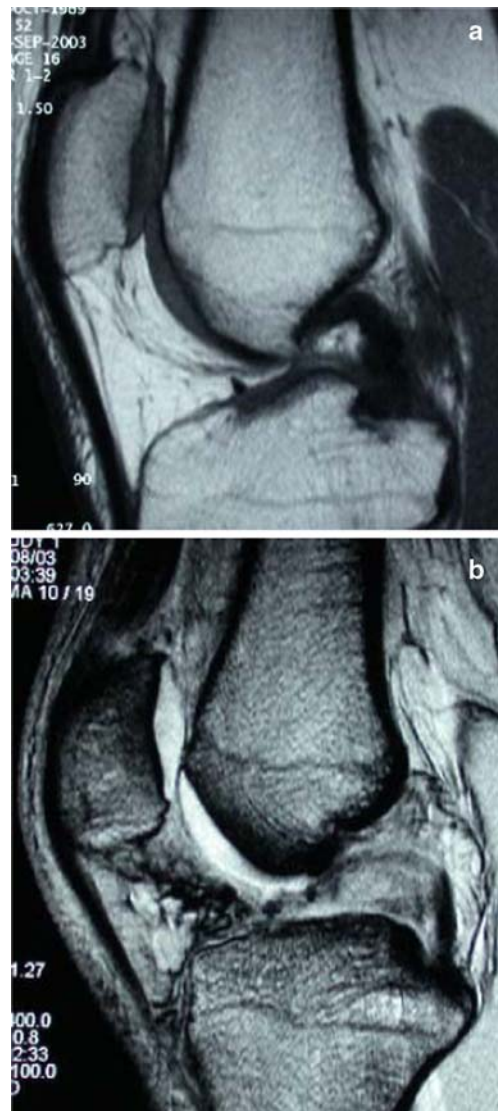


Fig. 6 The distal femoral physal scar does not correspond with the superior most aspect of the trochlear articular cartilage. Note also the variations of form and length of the trochlear cartilage. **a** Physal scar too distal and raising anteriorly. **b** Physal scar too proximal

If abnormal patellar height (alta or infera) is considered to be the underlying pathology in the patellofemoral joint causing instability or pain, then an MRI is recommended, especially if conservative treatment was not successful, and surgery may be considered. The patellochlear index describes the real articular cartilage relationship. Sagittal MRI might therefore be helpful to plan precisely any distalization or proximalization of the patella. Additional axial views show the condition and real congruence of the articular cartilage, and all types of trochlear dysplasia may be depicted.

In conclusion, the described patellochlear index documents the individual's real articular cartilage relationship in the patellofemoral joint and represents another method to measure precisely patellar height.

The presented technique of measurement has also limitations. First, the control of conscious quadriceps muscle relaxation was difficult (no artifacts on the images were accepted). Second, no weight bearing was possible. Third, imaging in greater flexion angles (30° or 60°) has not yet been performed for comparison. Fourth, no repeat MRIs were done on the same patient. Further studies are needed to assess: (1) the reliability of this measurement on successive MRIs in the same patient, (2) how the amount of quadriceps contraction influences this reading, and (3) whether this reading has any validity to the patellofemoral pathology.

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