The lateral condyle index: a new index for assessing the length of the lateral articular trochlea as predisposing factor for patellar instability

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Abstract The central trochlea has been considered as the major location of dysplasia. The purpose of this study was to investigate the influence of the lateral trochlea on patellar stability and to establish a new method for measuring the lateral trochlea on sagittal magnetic resonance (MR) images. Twenty-eight knees of 23 patients suffering from lateral patellar subluxation (12 knees with radiological signs of central trochlear dysplasia) and of 46 patients without patellofemoral complaints (without central trochlear dysplasia) were analysed. The lateral condyle index was designed to measure the lateral trochlea by comparing the anterior cartilaginous trochlea (a) and the posterior aspect (p) [(a:p) × 100]. The lateral condyle index showed high interrater reliability ($r=.94$) and was significantly ($p<0.001$) lower in symptomatic patients (86%) than in the control group (93%). These results show high clinical relevance of the lateral trochlea as another factor for patellar instability.

Introduction

The aetiology of patellar instability is multifactorial, and both surgical and conservative treatment options are diverse [1–6]. Trochlear dysplasia is considered to be one of the most relevant factors of patellar instability [2, 5, 7–12]. To date, trochlear dysplasia has been defined as a

flat, articular zone of variable length, which is situated proximally and is associated with a shallow groove distally [2]. Dejour et al. [2, 9, 12] described four types of trochlear dysplasia (A–D) based on true lateral radiographs in which the trochlea has only a shallow (<4 mm) or no groove, or even a trochlear bump (anterior translation of the trochlear floor). However, the proximal extent of the cartilaginous lateral, central and medial trochlea has never been described.

In the last decade, we have observed an additional type of trochlear dysplasia, which has to our knowledge not been described before: a lateral articular trochlea that is too short. We believe that a short lateral trochlea might be another relevant factor in lateral patellar instability by failing to stabilise the patella close to extension. The aims of this study were to: (1) develop a new method of measuring the length of the articular part of the lateral trochlea on the basis of sagittal magnetic resonance (MR) images (lateral condyle index); (2) build a prospective data pool on the length of the lateral trochlea of individuals without patellofemoral complaints to create standard values; and (3) compare these data with patients suffering from documented lateral patellar subluxation on plain X-rays and axial computed tomography (CT) scans.

Material and methods

Patients with lateral patellar subluxation (diseased group)

Over a period of two years, we evaluated the MR examinations of 28 knees of 23 patients suffering from lateral patellar subluxation defined as a partial loss of the articular congruence between patella and trochlea occurring close to extension (0–30°), with or without quadriceps contraction.

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Patients with normal patellofemoral joint (control group)

During the same period we also evaluated the MR examinations of the knee of 46 patients with no history of patellofemoral complaints. The physical examination revealed normal patellofemoral function with no signs of patellar instability, and in particular without lateral patellar subluxation. The most common clinical indication was for assessment of meniscal lesions or anterior cruciate ligament (ACL) ruptures.

Conventional X-ray examination

X-ray analysis consisted of anteroposterior (AP) views and true sagittal views in monopodal weight bearing with 30° of knee flexion. Special attention was given to the signs of trochlear dysplasia described by Dejour et al. [2, 9, 12], such as crossing sign, supratrochlear spur and double contour.

Axial CT scans

Axial computed tomography (CT) scans were taken in extension with and without quadriceps contraction with the legs fixed to prevent excessive femoral external rotation. CT scans documented the axial osseous morphology of the trochlea and lateral patellar subluxation and the influence of voluntary muscle contraction.

MR measurements

MR imaging was conducted on 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. All measurements were performed on sagittal images (Fig. 1a and b). Firstly, on sagittal images showing the ACL in its entire length, the central longitudinal axis (Ca) of the femoral shaft is defined by drawing a proximal and a distal circle (C1 and C2, respectively) and connecting the centres of the two circles. Secondly, the most lateral sagittal image on which the articular cartilage of the lateral condyle still can be seen is selected. A tangent line (d) on the distal femoral cartilage is drawn at 90° to the femoral axis (Ca). The length (a and p) to the most anterior (A) and the most posterior (P) aspect of the cartilaginous part is measured in relation to the tangent line. Its ratio ($[a:p] \times 100$) represents the lateral condyle index in percentages.

In addition, the tibial tuberosity to trochlear groove distance (TT–TG) was measured on axial planes [13]. Documentation of the patellar height was calculated on sagittal MR images using the patellotrochlear index [14]. Compared with other measurement methods, this has been shown to be the most clinical relevant [15, 16]. The measurements were assessed independently by three raters: one radiologist (IG), and one experienced (PN) and one inexperienced (PT) orthopaedic surgeon. All were blinded to patient data.

Statistical analysis

All analyses were undertaken by an uninvolved specialist in biostatistics using PASW Statistics 17.0 (SPSS Inc., Chicago, IL, USA). Data are presented as means with standard deviation (SD) and range. Measurements of length of anterior condyle (a) and posterior condyle (p) were analysed using analysis of variance for repeated measures (ANOVA).

Fig. 1 Magnetic resonance measurements of the lateral condyle index [5]. **a** Measurement of the central axis (Ca): C1 proximal circle in the femoral shaft, C2 distal circle in the femoral shaft. **b** Measurements of the anterior and posterior cartilage length: d baseline distal condyle (perpendicular to Ca), A superior most aspect of anterior cartilage of the lateral condyle, P superior most aspect of the posterior cartilage of the lateral condyle, a length of the anterior articular cartilage of the lateral condyle (red line), p length of the posterior articular cartilage of the lateral condyle (blue line)

Interrater reliability of lateral condyle index and cartilaginous height of the anterior condyle (a) and posterior condyle (p) was assessed using intraclass correlations (ICC). The lateral condyle index was computed using mean measurements of a and p by the three raters. The lateral condyle index and age were compared between diseased and control individuals using the unpaired *t* test. Pearson correlations between age and lateral condyle index were analysed. *P* values ≤ 0.05 are considered statistically significant.

Results

Patients

The mean age of patients with normal patellofemoral joints (36 male and 10 female patients) was 40 ± 16 (range 15–70) years, differing significantly from patients with lateral patellar subluxation (13 male and 12 female patients; 28 ± 12 years; 14–47; $p=0.006$). However, no correlation between the lateral condyle index and age was found for either group.

Conventional X-ray examinations and axial CT scans

No radiological signs of trochlear dysplasia were found in the control group. In the patient group with lateral patellar subluxation, signs showing a dysplastic trochlea were found in 12 knees (42.8%). In five knees (17.8%), the trochlea was flat, and in seven knees (25%), a central bump could be detected. Sixteen knees (57.2%) had none of the typical radiological signs of trochlear dysplasia.

MR measurements

Measurements for the lateral condyle index ($r=0.941$), the cartilaginous length of the anterior condyle ($r=0.910$) and

posterior condyle ($r=0.891$) showed high correlation between the three raters. The mean lateral condyle index was $93 \pm 7\%$ (range 73–109%) for patients with normal patellofemoral joints (Fig. 2) and $86 \pm 9\%$ (range 63–104%) for the diseased group (Fig. 3). The independent sample *t* test showed a statistically significant difference of the lateral condyle index between patients with lateral patellar subluxation and the control group ($p<0.001$). No significant difference was found between genders with regard to the lateral condyle index.

A lateral condyle index $\leq 90\%$ has a sensitivity of 79% and a specificity of 37% for a lateral cartilaginous condyle that is too short. The patellotrochlear index was 0.29 ± 0.1 for the diseased group (range 0.18–0.53; median 0.26) and 0.33 ± 0.1 in the control group (range 0.19–0.53; median 0.33). Mean TT–TG distance was 11.7 ± 3.1 mm in the diseased group. No patient showed pathological TT–TG distance (range 8–18 mm).

Discussion

The results of this study show that the described lateral condyle index measured on sagittal MR images is a reliable and reproducible method to determine the length of the lateral articular trochlea. According to our results, a normal length of the articular lateral trochlea can be considered to be at least 90% of the posterior articular lateral condyle. A short lateral trochlea is present when the anterior part is $<90\%$ of the length of the posterior articular lateral condyle. Normally, the lateral facet of the trochlea is longer, wider and higher than the medial facet anteriorly [17]. The large lateral facet in extension is the feature that must “capture” the patella when the knee starts to flex to ensure that it is guided into the trochlear groove. Normally, contact between the articular surface of the trochlea and the articular cartilage behind the patella is about one third of the length

Fig. 2 Magnetic resonance measurements with normal length of the anterior articular cartilage of the trochlea lateral facet. The lateral condyle index is 95%. Ca central axis, C1 proximal circle in the femoral shaft, C2 distal circle in the femoral shaft

Fig. 3 Magnetic resonance (MR) measurement showing an anterior articular cartilage of the trochlea lateral facet that is too short. The lateral condyle index on sagittal MR is 63%. *Ca* central axis, *A* superior most aspect of anterior cartilage of the lateral condyle, *P* superior most aspect of the posterior cartilage of the lateral condyle, *a* length of the anterior articular cartilage of the lateral condyle (red line), *p* length of the posterior articular cartilage of the lateral condyle (blue line), *d* baseline distal condyle (perpendicular to *Ca*)

of the patellar cartilage (measured using the patellochlear index) [14]. In this normal situation, quadriceps muscle contraction causes only proximalisation of the patella without lateral subluxation, as the patella is still guided by the most proximal shape of the lateral trochlea. In patients with short lateral articular trochlea, contraction of the quadriceps muscle causes proximalisation with additional lateralisation of the patella due to the missing lateral trochlea that resists pathological lateral patellar movement. This differentiation is not only helpful but mandatory to select the necessary therapy to treat lateral patellar subluxation more precisely and to individually tailor the surgical treatment to the underlying pathology.

The clinical relevance of our findings is the high number of normal radiographs in patients with lateral patellar subluxation with missing radiological signs of trochlear dysplasia corresponding to Dejour et al. [3]. In addition, we found no pathological MR signs for abnormal patella height or TT–TG distance [14, 15], which would merit specific surgical considerations [12, 18]. Therefore, another underlying pathomorphology other than those described by Dejour et al. [2, 12] must be present for proximal lateral patellar subluxation close to extension. The documented (too) short lateral articular trochlea quantified by the lateral condyle index could be a relevant factor for lateral patellar instability. Besides the flat or even prominent (central bump) proximal trochlea [2], this could be another important pathology and a different type of trochlear dysplasia with clinical relevance.

Surgical procedures that aim to steepen the slope of the lateral facet of the femoral trochlear surface are logical from the mechanical point of view. The Albee procedure [19], which raises the lateral edge of the trochlea in cases with a flat trochlea, has the desired effect, but the additional bony prominence may then cause problems by overtightening the lateral retinacular structures or by increased pressure across

the lateral facet of the patellofemoral articulation with the potential to generate pain or osteoarthritis [5]. Apart from these effects, raising the lateral edge of the trochlea does not correct an abnormal length of the lateral trochlea. In patients presenting with a trochlear bump, Bereiter and Gautier [20] described the trochleaplasty for remodelling a flattened trochlear groove [5, 20]. This is a challenging surgical procedure to restore patellofemoral stability and is performed mostly in young patients with possible technical (fracture of the osteochondral flake, insufficient flake fixation) and/or postoperative complications (persistent pain, tendency for subluxation, patella infera, development of osteoarthritis) [5]. Therefore, this procedure should be performed only for an unequivocal indication and by an experienced surgeon. All symptomatic patients in our study underwent proximal lateral trochlear osteotomy with lengthening where no cartilaginous surface was present (Fig. 4). Cancellous bone was removed from the ipsilateral

Fig. 4 Intra-articular inspection shows an articular cartilage of the trochlear lateral facet that is too short (arrow), with signs of patellar subluxation (cartilage destruction)

lateral femoral condyle and inserted into the osteotomy gap. Technical details were described recently [21].

A combined trochlear dysplasia with a shallow trochlear groove seen on axial planes or lateral radiographs and a (too) short lateral trochlea quantified by the lateral condyle index on sagittal planes may simultaneously be present. Ongoing clinical trials will need to show whether this new pathomorphological finding in patellofemoral dysplasia can be treated by a lateral trochlear osteotomy and whether a more detailed classification of trochlear dysplasia is anatomically and—last but not least—clinically relevant for symptoms and treatment.

In summary, we think that the (too) short lateral articular trochlea is another relevant factor in lateral patellar instability. The lateral condyle index described, is a reliable and reproducible method for assessing the length of the lateral trochlea and defining exactly the patients suffering from a short lateral trochlea with lateral patellar instability. This index can be used to differentiate between a normal-length lateral articular trochlea and a pathological length. The results of our study showed that the interobserver variability using the described index was high. Surgical procedures should address the precise underlying pathology in the described topic: the short lateral trochlea. Lengthening of the lateral trochlea might be an appropriate and less invasive solution to knee instability.

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