Axial MRI index of patellar engagement: A new method to assess patellar instability


Introduction: The aim of this study was to define a new index to measure lateral patellar displacement (LPD) using nuclear magnetic resonance imaging (MRI), an axial index of engagement of the patella (AEI) obtained from two different axial MRI views then to validate its use in a prospective series of patients presenting an objective patellar instability (OPI).

Materials and methods: One hundred and thirty-five patients with OPI and no history of surgery of the patella were included in a prospective study organized by the French Society of Arthroscopy performed between June 2010 and August 2012. All patients underwent axial and sagittal MRI. The AEI was obtained by projecting predefined patellar and trochlear landmarks (cartilaginous landmarks) on 2 different axial MRI views (one trochlear and one patellar). The results were compared with a series of controls (n = 45).
Introduction

Objective patellar instability (OPI) has been the subject of numerous publications in the literature especially its anatomical and clinical features. In particular, lateral patellar displacement (LPD) on the axial plane has long been of interest to surgeons. It has been evaluated by a clinical examination [1–3], standard radiological imaging [4,5] then CT scan [6–8]. MRI has made it possible to evaluate bone anomalies (trochlear dysplasia [9] and the TT-TG distance [10], by transposing the measurements obtained by CT scan), but also cartilage [11], and soft tissue (in particular the medial patellofemoral ligament [MPFL]) [12].

Thus, MRI has become essential, especially since it provides a 3D assessment of the position of the patella in space: on the sagittal plane it evaluates patellar height [13], while on the axial plane, patellar tilt and lateral displacement can be visualized. Measurement of LPD is essential because it indicates the severity of patellar instability. Reports of its measurement in the literature remain insufficient because it is imprecise or difficult to reproduce [7,9,14–18] (Fig. 1) and our goal was to improve this.

The goal of this study was:

- to evaluate lateral displacement of the patella in relation to the trochlea on MRI by defining a new index, the patellofemoral axial engagement index (AEI), (Fig. 2) using precise and reliable landmarks for measurements;
- to validate the AEI in a study based on a prospective series of patients presenting with OPI compared to results obtained in a control group.

Materials and methods

A non-randomized prospective multicenter study was performed in 9 surgical centers by the French Society of Arthroscopy (Société française d’arthroscopie, SFA). Patients who were included had OPI with at least one recorded episode of dislocation. Patients with other causes of patellar instability were excluded (ACL tear, subjective patellar instability) as well as patients with tibiofemoral or patellofemoral osteoarthritis.

One hundred and seventy one patients were included between June 2010 and August 2012. One hundred thirty five of these patients (56% women, mean age 24.6 ± 9.3 years old, BMI 22.5 ± 3.84 kg/m²) had no history of surgery. Only these 135 patients underwent MRI.

A control group of 45 subjects with no patellofemoral pain was used to compare MRI measurements. None of the subjects in the control group had any history or clinical signs suggesting patellofemoral disease.

All of the patients underwent standard radiographic and MRI examinations.

Examinations were performed in participating centers with the patient in the supine position with the knee nearly extended, placed in a specific antenna/coil for detection.

Measurement of AEI was obtained with 2 different axial MRI views (Fig. 3). Like patellar tilt (PT) (Fig. 4), the measurement of AEI used cartilaginous and posterior condylar landmarks as references. A torn MPFL and its insertion site was also looked for, as well as the lateral trochlear inclination.

Patellar height was measured on sagittal MRI (Fig. 5) as well as the patellofemoral sagittal engagement index (SEI) (Fig. 6), which was also obtained with 2 different MRI views. Measurements were performed using free imaging software Osirix® [19], (Pixmeo®, Geneva, Switzerland.).

Statistical analyses were performed with R version 2.14.1-1 (http://www.r-project.org/) software. Comparisons of two means were obtained with a Welch T test. The dependence of numerical variables such as AEI on factors such as dysplasia was assessed by 1-factor analyses of variance with a linear model. Correlations of pairs of numerical variables were estimated by the Spearman correlation coefficient. The hypothesis that this coefficient was equal to 0 was tested. Asymptotic convergence theorems such as the central limit theorem for the mean guarantee that non-parametric tests do not provide more favorable results than the parametric tests used in this study. Indeed, the amount of data used in each test were sufficient to guarantee convergence of the indicators being studied. P < 0.05 was considered to be significant.
Figure 1 Main measurements of patellar displacement published in the literature. a: "LPD" described for 30° LPD by Laurin et al. [4], using the anterior trochlea as a landmark; b: "LPD" reported by Muhle et al. [16] with kinematic MRI, using the posterior condyle as a landmark; c: "Tangent offset" described by Stanford et al. [14] on dynamic CT scan, using the tangent of the cortex of the lateral trochlea as a bone landmark. Measurement used on MRI by Pfirrmann et al. [17]; d: "Lateral shift" described by Sasaki et al. [6] on dynamic CT scan using an anterior landmark; e: "Bisect offset" described by Stanford et al. [14] on dynamic CT scan using a posterior landmark; f: "LPL" described on X-ray by Brossman et al. [7], used with dynamic MRI by Duchman et al. [15] and in a cadaver study by Nicolaas et al. [21], using an anterior trochlear landmark. All of these measurements were obtained with a single view where the patella was the widest.

Figure 2 Diagram to measure the patellofemoral axial engagement index on MRI (a step by step description of the measurement is described in Fig. 3). Note the landmark of the posterior condyle. Two views were used to identify trochlear and patellar cartilaginous landmarks.

Results

Radiological results

It was found that 87.2% of the patients had femoral trochlear dysplasia according to the Dejour classification [20] (type A: 28.4%, B: 28.4%, C: 16.4%, D: 26.7%). Patellar height according to Caton and Deschamps was 1.18 ± 0.18.

MRI results

The AEI could always be measured when 2 different axial views were obtained. The AEI could not be measured in 38.5% of cases when only one axial MRI view was obtained. Indeed, on the axial view where the patella was the widest, the trochlea was not visible in 38.5% of the cases (Fig. 7).

The AEI was 0.84 ± 0.16 in patients with OPI compared to 0.94 ± 0.09 in controls (t(114) = −5.32, P < 0.000001).

No correlation was found between AEI and age, gender, height, weight, BMI, number of dislocations, radiological index of patellar height or MRI, patellofemoral sagittal engagement index, visualization or not of an MPFL tear on MRI or at the insertion site or measurement of lateral trochlear inclination.
Figure 3  Description of MRI measurement of patellofemoral AEI. a: selection of axial MRI view where the lateral border of the trochlea is largest. The posterior bicondylar axis "BC" is drawn (or transferred to this view if the posterior condyles are more prominent on another view). The most lateral point of the lateral border of the trochlea is identified (arrow) and the line "'T'" is drawn from this point, perpendicular to "BC"; b: selection of the axial MRI view where the patella is the widest. The lines "'T'" and "'BC" are transferred. The most medial point of the patellar cartilage is identified and the line "'P'" is drawn from this point perpendicular to "BC"; c: the line "'LT'" (projected length of the surface of the joint engaged in the trochlea) is drawn between the lines "'T'" and "'P'" and is perpendicular to them. The most lateral cartilaginous point of the patella is identified and the line "'LP'" (projected width of the total patellar surface) is drawn from this point to the line "'P'" and perpendicular to it. The AEI of the patella is equal to LT/LP.

An analysis of variance suggests that the AEI did not significantly depend on the dysplasia values (F(3,108) = 1.15; P = 0.33) (Table 1). The mean AEI of the dysplasias with or without a supratrochlear spur were not significantly different (t(98) = 1.46; P = 0.15). The AEI was lower if trochlear prominence was increased on MRI (cor = −0.44; t(114) = −5.25, P < 0.000001).

The AEI was negatively correlated with the TT-TG distance (r < 0.0001, r = −0.47) and patellar tilt (cor = −0.55; t(128) = −7.43; P < 0.000001).

Table 2 compares the means of a few MRI indexes for the series of 135 OPI and for the control group.

Discussion
This is one of the largest series of OPI in the literature with 135 patients compared to 45 control subjects. The AEI is a new index of measurement for LPD and is a direct reflection of this entity, unlike PT, which is indirect. The AEI was obtained from two different axial MRI views, which in our experience, could always be measured. The normal value is close to 1. Lower values indicated more severe forms of OPI and were correlated with trochlear dysplasia with supratrochlear spur and increased trochlear prominence. A study evaluating the reproducibility of AEI is needed.

Table 1  Results of the AEI in relation to trochlear dysplasia according to Dejour and the presence or not of supratrochlear spur (mean ± standard deviation).

<table>
<thead>
<tr>
<th>Dysplasia according to Dejour</th>
<th>No dysplasia</th>
<th>A</th>
<th>C</th>
<th>B</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI (P = 0.33)</td>
<td>0.91 ± 0.10</td>
<td>0.86 ± 0.10</td>
<td>0.82 ± 0.13</td>
<td>0.79 ± 0.23</td>
<td>0.82 ± 0.17</td>
</tr>
<tr>
<td>Dysplasia with or without supratrochlear spur</td>
<td>Absent</td>
<td>Dysplasia without supratrochlear spur</td>
<td>Dysplasia with supratrochlear spur (= stages B and D)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AEI (P = 0.15)</td>
<td>0.91 ± 0.10</td>
<td>0.85 ± 0.11</td>
<td>0.80 ± 0.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AEI: axial index of engagement.

Table 2  Main results of axial and sagittal MRI in the SFA OPI series and the control group (mean ± standard deviation).

<table>
<thead>
<tr>
<th>Preop. MRI results</th>
<th>AEI</th>
<th>Patellar tilt</th>
<th>TT-TG</th>
<th>Index of patellar height</th>
<th>Trochlear prominence</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFA series (n = 135)</td>
<td>0.84 ± 0.16</td>
<td>15.38 ± 9.11</td>
<td>13.38 ± 9.44 mm</td>
<td>1.18 ± 0.18</td>
<td>3.91 ± 1.81</td>
</tr>
<tr>
<td>Controls (n = 45)</td>
<td>0.94 ± 0.09</td>
<td>6.68 ± 5.00</td>
<td>8.57 ± 4.30 mm</td>
<td>0.92 ± 0.11</td>
<td>1.05 ± 0.62</td>
</tr>
<tr>
<td>P</td>
<td>&lt; 0.000001</td>
<td>&lt; 0.000001</td>
<td>&lt; 0.000001</td>
<td>&lt; 0.01</td>
<td>&lt; 0.000001</td>
</tr>
</tbody>
</table>

MRI: magnetic resonance imaging; AEI: axial index of engagement; SFA: Société française d’arthroscopie; OPI: objective patellar instability.
Delgado et al. [18] measured the ‘‘lateral shift’’ described by Sasaki et al. [6] (Fig. 1d) on CT scan and noted that this measurement could not be obtained when the patella was significantly lateralized (5/126 cases could not be measured in that study). They also analyzed reproducibility, which they found to be mediocre, in part for this reason, but also perhaps because of the choice of landmarks which were not extremely precise. We solved this problem by using two independent views, the posterior condyles as a line of reference, and cartilage landmarks. Nicolaas et al. [21] studied 51 asymptomatic subjects and showed that inter- and intra-observer reproducibility was good for LPD on MRI using landmarks that were similar to ours. An analysis of the reproducibility of AEI is still needed.

Historically, Laurin et al. [4] (Fig. 1a) were the first to measure LPD in a radiographic study and chose the medial borders of the patella and the trochlea. Sasaki et al. [6] used these same landmarks on CT scan, then Muhle et al. [16] (Fig. 1b) suggested using them for MRI. We did not use the medial border of the trochlea because it is often hypoplastic in severe forms of femoral trochlear dysplasia [22,23] which reduces the precision of this measurement. We did not choose the trochlear groove as a landmark for the same reason [14,24] because it is difficult to identify in patients with femoral trochlear dysplasia [22,23]. We chose the most external ridge of cartilage on the lateral facet of the trochlea, which we feel is more precise.

Like others [14,16,25], we chose the posterior bicondylar line as a reference because it is reliable and easy to identify. Cartilage landmarks on the patella and the trochlea, which are more precise than bone landmarks, and which can be obtained on MRI, seemed to be more logical for articular measurements. Charles et al. [26] has shown that MRI can be used to visualize patellofemoral diseases and that all measurements previously obtained on CT scan can be obtained on MRI. Like Stäubli et al. [9], we observed a difference between the anatomy of the underlying bone and

In our prospective multicenter study, the most important information was the importance of LPD measured by AEI on MRI and obtained by the projection of 2 different axial views. There is no comparable study in the literature. The first view was chosen so that the lateral rim of the trochlea was wider and the second view where the patella was wider. Thanks to this method, the AEI could always be measured in a series of patients with OPI, including in cases of patella alta or whenever sagittal engagement of the patella on the trochlea was not its widest.

Several teams have focused on kinematic imaging [7,16], but this approach is less sensitive to this problem. We felt that the nearly extended position of the knee was interesting because in this position LPD is maximal in patients with OPI.

Delgado et al. [18] measured the ‘‘lateral shift’’ described by Sasaki et al. [6] (Fig. 1d) on CT scan and noted that this measurement could not be obtained when the patella was significantly lateralized (5/126 cases could not be measured in that study). They also analyzed reproducibility, which they found to be mediocre, in part for this reason, but also perhaps because of the choice of landmarks which were not extremely precise. We solved this problem by using two independent views, the posterior condyles as a line of reference, and cartilage landmarks. Nicolaas et al. [21] studied 51 asymptomatic subjects and showed that inter- and intra-observer reproducibility was good for LPD on MRI using landmarks that were similar to ours. An analysis of the reproducibility of AEI is still needed.

Historically, Laurin et al. [4] (Fig. 1a) were the first to measure LPD in a radiographic study and chose the medial borders of the patella and the trochlea. Sasaki et al. [6] used these same landmarks on CT scan, then Muhle et al. [16] (Fig. 1b) suggested using them for MRI. We did not use the medial border of the trochlea because it is often hypoplastic in severe forms of femoral trochlear dysplasia [22,23] which reduces the precision of this measurement. We did not choose the trochlear groove as a landmark for the same reason [14,24] because it is difficult to identify in patients with femoral trochlear dysplasia [22,23]. We chose the most external ridge of cartilage on the lateral facet of the trochlea, which we feel is more precise.

Like others [14,16,25], we chose the posterior bicondylar line as a reference because it is reliable and easy to identify. Cartilage landmarks on the patella and the trochlea, which are more precise than bone landmarks, and which can be obtained on MRI, seemed to be more logical for articular measurements. Charles et al. [26] has shown that MRI can be used to visualize patellofemoral diseases and that all measurements previously obtained on CT scan can be obtained on MRI. Like Stäubli et al. [9], we observed a difference between the anatomy of the underlying bone and
Figure 6  Description of MRI measurement of the patellofemoral sagittal engagement index. a: selection of the sagittal MRI where the patella is the longest. Identification of the most proximal and distal points on the articular surface (arrows). A line ‘’LP’’ is drawn between these two points; b: selection of sagittal MRI view where the trochlea is the longest. The line ‘’LP’’ is transferred onto this. The point of cartilage that is most proximal to the trochlea is indentified (arrow); c: the line ‘’LT’’ is drawn from this point, parallel to ‘’LT’’ and ending in a line perpendicular to ‘’LT’’ passing by its most distal point. The sagittal engagement index of the patella is equal to \( \frac{LT}{LP} \).

Figure 7  Example of a view where the patellar is widest and the trochlea is not visible, which makes it impossible to measure the AEI if only one view is used.

Like Sasaki et al. [6], then Stanford et al. [14], we chose a ratio and not an absolute value. In this way, an index was independent of gender and morphometric data. Multiplied by 100, this index indicated the percentage of the cartilaginous patella that was ‘’engaged’’ on the trochlea. A normal AEI value is close to 1 in controls, which indicates complete transversal engagement of the patella in patients without patellar instability.

In clinical practice, the AEI can be used to identify the severity of LPD, and therefore the severity of patellar instability. The lowest values indicated more severe patellar displacement, and were found in cases of dysplasia with supratrochlear spur and increased trochlear prominence. Limited axial engagement was also associated with increased PT and TT-TG distance. AEI makes it possible to obtain a precise idea of the severity of LPD, which is directly reflected in this index. Although there is a strong correlation between PT and TT-TG distance this is only an indirect reflection of LPD. Thus, AEI provides a more precise evaluation of LPD. The reproducibility of this index needs to be tested. In an MRI study of OPI in a group of 46 patients and 69 controls, Escala et al. [27] showed that the best sensitivity and specificity (92.7%) to differentiate between the 2 groups was an increase in PT, then dysplasia of the femoral trochlea (85.7%). It would be interesting to identify the role of AEI in a similar study.

Conclusion

AEI is a new MRI index to directly assess the severity of patellar instability by measuring lateral patellar displacement (LPD). It can be obtained in all cases because it is obtained with 2 different axial views, one trochlear and one patellar. It provides direct measurement of LPD. The normal value is close to 1 in controls. In our series of 135 patients with OPI the AEI was \( 0.83 \pm 0.16 \), which was statistically
different from controls. The AEI values were not associated with femoral trochlear dysplasia with supratrochlear spur but they were associated with trochlear prominence.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References