Magnetic resonance imaging of the patella
A COMPARISON OF THE MORPHOLOGY OF THE PATELLA IN NORMAL AND DYSPLASTIC KNEES

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We retrospectively analysed the MR scans of 25 patients with patellofemoral dysplasia and ten control subjects, to assess whether there was any change in the morphology of the patella along its vertical length. Ratios were calculated comparing the size of the cartilaginous and subchondral osseous surfaces of the lateral and medial facets. We also classified the morphology using the scoring systems of Baumgartl and Wiberg. There were 18 females and seven males with a mean age of 20.2 years (10 to 29) with dysplasia and two females and eight males with a mean age of 20.4 years (10 to 29) in the control group.

In the patient group there was a significant difference in morphology from proximal to distal for the cartilaginous (Analysis of variance (ANOVA) \( p = 0.004 \)) and subchondral osseous surfaces (ANOVA, \( p = 0.002 \)). In the control group there was no significant difference for either the cartilaginous (ANOVA, \( p = 0.391 \)) or the subchondral osseous surface (ANOVA, \( p = 0.526 \)).

Our study has shown that in the dysplastic patellofemoral articulation the medial facet of the patella becomes smaller in relation to the lateral facet from proximal to distal. MRI is needed to define clearly the cartilaginous and osseous morphology of the patella before surgery is considered for patients with patellofemoral dysplasia.

Described by Reider et al.\(^1\) as being “poised like a shield on the anterior surface of the femoral condyles”, the patella is a complex bone associated with a number of different patellofemoral disorders. Detailed knowledge of its anatomy is required in order to understand the conditions which affect it. Much work has been done in the past studying its morphology both anatomically,\(^1-5\) radiologically\(^2,3,5,6\) and by using MRI.\(^6-9\) This study has used MRI to assess the morphology of the patella throughout its course in both normal and dysplastic knees. It is incorrect to assume that it has the same profile throughout its vertical length.

Patients and Methods
We reviewed retrospectively the MR scans of 25 knees in 25 patients with symptomatic recurrent atraumatic instability of the patella and patellofemoral dysplasia seen by one consultant (JDJE) between March 2002 and February 2005. There were 18 females and seven males with a mean age of 20.2 years (10 to 29). There were nine MR scans of the right knee and 16 of the left. The MR scans of ten knees in ten patients without patellofemoral dysplasia were selected at random to produce an age-matched control group. These were also reviewed retrospectively. This group comprised two females and eight males with a mean age of 20.4 years (10 to 29). There were six right and four left knees.

The scans were taken using a dedicated knee coil on a 1.0 Tesla MR scanner (Magnetom Impact Expert; Siemens Medical Systems, Ehrlangen, Germany) or a 1.5 Tesla scanner (Symphony Maestro; Siemens Medical Systems). The sequences examined were the axial fat saturation flash 3D gradient echo (FSE3d; flip angle, 40°; TR 50 ms; TE, 11 ms; slice thickness, 3 mm; field of view, 150 mm; matrix 192 \( \times \) 256, single acquisition over three minutes 52 seconds) on the first scanner and the axial fat saturation proton density (TR, 3150 ms; TE, 14 ms; slice thickness, 3 mm; field of view 150 mm, matrix 212 \( \times \) 256, single acquisition over two minutes 50 seconds) on the second scanner. The images were loaded on to the Leonardo workstation (Siemens Medical Systems) using Syngo post-processing software (Siemens Medical Systems). Proximal, middle and distal coronal slices of each patella were examined. The proximal slice was the first section through the patella in which hyaline cartilage could be reliably seen and the distal slice represented the last section in which cartilage...
and distal ratios were compared within and between these son of the cartilaginous and osseous contours of the patella and distal slices of each patella were analysed. A compari-
lateral compared with the medial facet.

The lc:ms and ls:ms ratios from the proximal, middle
analysis to remove skewness. Non-parametric methods
non-parametric methods were used to make group comparisons of the scores of Baumgart\textsuperscript{2} and Wiberg.\textsuperscript{5} The Friedman test was used to compare the three sites and the Mann-Whitney U-test for the patients and the control group. A 5% level of significance was used throughout.

Measurements from the first author (AJB) were used for
the main analysis with intraobserver repeatability assessed by re-measurement by AJB after blinding to the initial mea-
sures. Within pair SDs were calculated to measure repeatability. The intraclass correlation was calculated as the variance between the subject-slice pairs expressed as a proportion of the total (between and within) variance.

To validate AJB’s measurements, two other authors
both intra- and interobserver agreement for the classifica-
tion of patellar shape, since these assessments could not be
analysed using ANOVA. For all the kappa statistics, 0.21 to
the shape of the patella defined by the ratios lc:ms and ls:ms
from proximal to distal in the patients and the control
group. The ratios were logarithmically transformed before

Results

Analysis of the lc:mc ratios (Table I) showed a statistically significant interaction (repeated-measures ANOVA, p = 0.014) indicating that the differences between the patellar morphology of the three slices, from proximal to distal, were not the same for the patients and the control group. Further analysis confirmed that there were significant differences in the three slices for the patients (p = 0.004), but not for the control group (p = 0.391). Although the patients’ proximal and middle ratios were lower than those of the control group and the distal ratios were higher, the differences did not achieve statistical significance (minimum p = 0.186).

Analysis of the ls:ms ratios (Table I) showed a similar sig-
ificant interaction (p = 0.02), with significant differences
between the three slices for the patients (p = 0.002), but not
for the control group (p = 0.526). The ratios for the patients
were higher than those of the control group although the
difference achieved significance only for middle and distal
slices (p = 0.018 and p < 0.001, respectively). The Wiberg\textsuperscript{5} and Baumgart\textsuperscript{2} scores differed significantly between the
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three slices for the patients (Friedman test, p = 0.001; Table I), but not for the control group (p = 0.223). The patients had significantly higher distal scores than the control group (Mann-Whitney U test, p = 0.028).

Intraobserver variability for the main observer (AJB) for bl, mc and ms was greater in the patients than in the control group (Table II). The mean within-pair SD for the control group was 0.19. Thus, an estimated 95% of the pairs of results would be expected to be within 0.5 (2.77 \times 0.19) units of each other. The mean intraclass correlation coefficient was 0.93 for the control group and 0.69 for the patients, the size of these reflecting the small within-pair variability compared with that between the subject/slices.

Interobserver agreement for patellar measurements was good in both the control group and the patients with a mean intraclass correlation coefficient of 0.88 and 0.82, respectively (Table III) suggesting that the measurements were reliable.

Intraobserver agreement was moderate to good for the Wiberg classification of patellar shape. The kappa statistic was 0.51 in the control group and 0.65 in the patients (0.62 for the combined group). In most assessments (80 of 99), the second result was identical to the first, with 17 of the remaining 18 showing a difference of only one point. There was moderate agreement between the three observers. The kappa statistics were 0.53 and 0.51, respectively, for the control group and the patients (mean scores 1.7 and 2.2), or 0.54 across both groups combined. Within the patients there was some evidence of systematic differences between the observers (Friedman test, p < 0.001), with both BJAL and ROEG scoring a mean of 0.4 points higher than AJB.

Discussion
Patellofemoral dysplasia is a condition affecting the extension facets of the joint. There are seven facets to the patella with the distal two articulating in extension. The distal patella would therefore be expected to be more affected in the dysplastic joint than the middle and proximal thirds.

Our study has shown that patellar shape changes from proximal to distal in dysplastic patellae (Fig. 2). Both the cartilaginous and osseous contours of the patella become more dysplastic along their length, as shown by the increase

Table I. The mean lc:mc, ls:ms ratios and the Wiberg classification for proximal, middle and distal patellar slices in the patients and control group

<table>
<thead>
<tr>
<th>Patellar slice</th>
<th>Proximal</th>
<th>Middle</th>
<th>Distal</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lc:mc ratio (mean, range)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients 1.61 (1.05 to 2.88)</td>
<td>1.64 (1.13 to 3.29)</td>
<td>2.05 (0.58 to 4.13)</td>
<td>0.004*</td>
<td></td>
</tr>
<tr>
<td>Control group 1.99 (1.22 to 5.47)</td>
<td>1.99 (1.11 to 5.01)</td>
<td>1.71 (0.91 to 5.78)</td>
<td>0.391</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.186*</td>
<td>0.225</td>
<td>0.256</td>
<td></td>
</tr>
<tr>
<td>Ls:ms ratio (mean, range)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients 1.88 (1.18 to 4.00)</td>
<td>1.99 (1.30 to 4.12)</td>
<td>2.49 (0.61 to 4.92)</td>
<td>0.002*</td>
<td></td>
</tr>
<tr>
<td>Control group 1.60 (1.09 to 2.35)</td>
<td>1.48 (0.94 to 2.56)</td>
<td>1.39 (1.06 to 2.04)</td>
<td>0.526</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.206</td>
<td>0.018</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Wiberg classification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients 2 (1.7) 1 to 2</td>
<td>2 (2.1) 1 to 4</td>
<td>2 (2.4) 1 to 4</td>
<td>0.001*</td>
<td></td>
</tr>
<tr>
<td>Control group 2 (1.9) 1 to 2</td>
<td>2 (1.8) 1 to 2</td>
<td>2 (1.7) 1 to 2</td>
<td>0.223*</td>
<td></td>
</tr>
</tbody>
</table>

* from repeated-measures ANOVA
† median (mean), range
‡ Friedman test

Table II. Intraobserver variability for the main observer (AJB)

<table>
<thead>
<tr>
<th>Measured variables</th>
<th>Control group</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall mean SD within subject/slice pairs ICC†</td>
<td>Overall mean SD within subject/slice pairs ICC†</td>
</tr>
<tr>
<td>bl</td>
<td>4.13</td>
<td>0.09</td>
</tr>
<tr>
<td>mc</td>
<td>1.80</td>
<td>0.13</td>
</tr>
<tr>
<td>ms</td>
<td>1.68</td>
<td>0.09</td>
</tr>
</tbody>
</table>

* SD, standard deviation
† ICC, intraclass correlation coefficient

Table III. Interobserver variability for three observers

<table>
<thead>
<tr>
<th>Measured variables</th>
<th>Control group</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall mean ICC†</td>
<td>Overall mean ICC†</td>
</tr>
<tr>
<td>bl</td>
<td>4.04</td>
<td>0.84</td>
</tr>
<tr>
<td>mc</td>
<td>1.84</td>
<td>0.88</td>
</tr>
<tr>
<td>ms</td>
<td>1.74</td>
<td>0.92</td>
</tr>
</tbody>
</table>

* ICC, intraclass correlation coefficient
in the ratios. However, in the normal control group there was little change in the ratios suggesting a more uniform shape throughout (Fig. 3). These results were all statistically significant. Intraobserver variability was greater in the patients than in the control group, probably due to the distorted anatomy seen in the dysplastic patella. Intraobserver agreement in the patients was moderate or good and very good in the control group. The measurements showed good reliability when interobserver variability was assessed.

In classifying morphology of the patella using the Baumgartl\textsuperscript{2} and Wiberg\textsuperscript{5} classifications, interobserver agreement was moderate while intraobserver agreement was moderate or good. We were unable to find any reports on intra- or interobserver variability in the classification of dysplasia of the patella, but in a study on the classification of femoral trochlear dysplasia using seven observers (two junior and five senior orthopaedic surgeons) Remy et al\textsuperscript{12} showed poor agreement (kappa = 0.17).

Many studies of the patellofemoral joint have been undertaken with and without MR scanning,\textsuperscript{1-9} but none has examined the variable shape of the patella in dysplastic knees. Staubli et al\textsuperscript{13} studied cryosections from a cadaver knee and the MR scans of 30 non-dysplastic knees. On both the cryosections and MR scans they found a difference between the geometry of the surface of the cartilage and the corresponding subchondral osseous anatomy of the femoral trochlea and patella. The cartilage and osseous morphology was seen to vary depending on the level of the axial plane and there was also significant intra- and interspecimen variation. Van Huyssteen et al\textsuperscript{8} showed a significant mismatch between the cartilaginous and the underlying bony morphology in patients with trochlear dysplasia. Their study looked solely at the trochlea. A number of patellar operations has been described for a variety of patellofemoral disorders.\textsuperscript{3,13-15} The Albee procedure\textsuperscript{13,16} for patellofemoral instability with dysplasia uses a closing-wedge patellar osteotomy and opening-wedge lateral femoral condylar osteotomy to reconstruct a stable, congruent articulation. Other operations such as femoral trochleoplasty aim to create a more congruent patellofemoral joint by fashioning a new trochlear groove. Our study has shown that in the dysplastic patella the medial facet becomes

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**Fig. 2a**

Axial MR scans of a left knee showing the change in shape of the patella from a) proximal to b) middle to c) distal in patellofemoral dysplasia. The medial facet becomes smaller and more vertical in relation to the lateral facet.

**Fig. 3a**

Axial MR scans of the right knee in a control subject showing uniformity of the patellar morphology from a) proximal to b) middle to c) distal. The medial and lateral facets are relatively equal in size throughout the course of the patella.
smaller in relation to the lateral facet from proximal to distal. It is a morphologically diverse bone in dysplastic patients and warrants careful clinical and radiological examination before any surgical correction is undertaken. In the presence of dysplasia, the effect of a patellar osteotomy is not consistent and could decrease the congruity of the patellofemoral joint in flexion. MRI is therefore beneficial in the assessment of the cartilaginous and osseous morphology of the patellofemoral joint before surgery is undertaken.

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References