Relationship between the distal trochlear groove angle and patellar cartilage morphology defined by 3D spoiled spoiled gradient-echo imaging

Poster No.: C-0317  
Congress: ECR 2012  
Type: Scientific Exhibit  
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Keywords: Arthritides, Imaging sequences, MR, Musculoskeletal joint  
DOI: 10.1594/ecr2012/C-0317  

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Purpose

To examine whether the distal femoral trochlear groove angle (TGA) is a determinant of the patellar cartilage volume and patellar cartilage damage.

The patellofemoral (PF) joint, which is formed by the articulation between the patella and femoral trochlear groove, is one example of a joint commonly affected by osteoarthritis (OA). Magnetic resonance (MR) imaging is a conventional technique for the evaluation of articular cartilage.

Previous studies have investigated the correlation between chondral defects and different radiographic and MR morphologic measurements (1, 2). The bony landmarks along the trochlear groove, which form the articular surface for the patella between the medial and lateral femoral condyles, have been recognized as an important factor in patellofemoral stability. A shallower femoral trochlear groove is associated with decreased PF congruency and stability (2-4). Some investigators previously reported that there is an associated increase in patellar cartilage volume as the femoral trochlear groove becomes more flattened in both healthy adults and OA patients (5, 6). It follows from this that a flattened trochlear groove may reduce the risk for knee pathology, such as OA, which is characterized by cartilage reduction.
Methods and Materials

Patients and status

A total of 80 patients, without a history of knee trauma within the previous 1 month, who underwent knee MR imaging from early 2006 until early 2008 to examine the cause of knee pain were included in this study. All participants granted their informed consent after receiving an explanation of the procedure, which was approved by our institutional review board.

The exclusion criteria for patients in this study were: age < 18 years (N = 6), a previous knee surgery (N = 4), malignancy (N = 0), and fracture (N = 4). To exclude unossified epiphyseal/apophyseal cartilage, subjects younger than 18 years old were not included in the present study. Finally, a total of 66 patients (22 males and 44 females) between the ages of 26 and 86 years (mean age, 60.7 years) took part in the present study. Only 16 patients underwent arthroscopy after MRI.

MR imaging

All MR examinations were performed on a 1.5T MR unit using a dedicated knee coil. First, the routine protocol was performed (Table 1).

Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Sagittal PD weighted FSE</th>
<th>Sagittal PD weighted FSE</th>
<th>Coronal PD weighted FSE</th>
<th>Coronal T2* weighted gradient-echo FSE</th>
<th>Axial PD weighted FSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>fat suppression</td>
<td>+</td>
<td>#</td>
<td>+</td>
<td>#</td>
<td>+</td>
</tr>
<tr>
<td>TR/TE (ms)</td>
<td>3000/25</td>
<td>2400/24</td>
<td>2800/25</td>
<td>425/15</td>
<td>3000/25</td>
</tr>
<tr>
<td>flip angle (°)</td>
<td>#</td>
<td>#</td>
<td>#</td>
<td>30</td>
<td>#</td>
</tr>
<tr>
<td>echo-train length</td>
<td>9</td>
<td>6</td>
<td>9</td>
<td>#</td>
<td>9</td>
</tr>
<tr>
<td>slice thickness / gap (mm)</td>
<td>4/0.8</td>
<td>4/0.8</td>
<td>4/0.8</td>
<td>4/0.8</td>
<td>4/0.8</td>
</tr>
</tbody>
</table>
In addition, sagittal fat-suppressed 3D spoiled gradient-echo images were obtained to calculate the cartilage volume. Sagittal fat-suppressed 3D spoiled gradient-echo images were obtained using the following parameters: TR/TE/FA = 39 msec/6.9 msec/45°, slice thickness = 2 mm, none gap, FOV = 18 cm, matrix = 192×256, total acquisition time = 5 minutes 8 seconds.

**Imaging analysis**

The articulate cartilage volumes were determined by means of 3D image processing at an independent work station. The volume of the patellar cartilage was isolated from the total volume by manually drawing disarticulation contours around the cartilage boundaries on a section by section basis. These data were then resampled by means of bilinear and cubic interpolation for the final 3D rendering. The cartilage contours were drawn twice 4 weeks apart, and the respective mean values were taken as the "cartilage volume" in the present study. The measurement of patellar bone volume was done using the same method as that used to determine the cartilage volume. These processes were all performed by one observer.

The TGA was measured at defined level at the distal aspects from axial PD weighted FSE MR images with fat suppression as previously described (5). The distal TGA was measured from the most inferior slice imaging through the trochlear groove that is immediately prior to the level at which the medial and lateral condyles separate (Fig. 1). This process was repeated by one observer at least two weeks after the first measurement, and the respective mean value was taken as the TGA.

The axial reformat fat-suppressed 3D spoiled gradient-echo images from the sagittal source images were evaluated for grading of the lesions of the patellar cartilage separately by two musculoskeletal radiologists. The readers were blinded to patient information during the evaluation. The MR grading of articular cartilage damage was based on a previously published arthroscopy classification adapted to MR imaging (1,
7-9). Grade 0 indicated intact cartilage. Grade 1 indicated either chondral softening or blistering with an intact surface. However, it was impossible to differentiate grade 1 from grade 0 based only on MR images. Consequently, in the present study, grade 0 and grade 1 were included in the same category, as grade 0/1. Grade 2 indicated a cartilage defect involving less than half of the articular cartilage thickness (Fig. 2). Grade 3 indicated cartilage defect involving more than half but less than the full thickness of the cartilage (Fig. 3). Grade 4 indicated cartilage defect involving the full thickness of the cartilage and exposed bone (Fig. 4). Cartilage at medial and lateral facets was evaluated separately.

**Statistical analysis**

The cartilage volume and bone volume of the patella were initially assessed for normality before being regressed against the distal TGA using linear regression. Linear regression was used to examine the effect of potential confounders (age, gender and bone volume) on cartilage volume in a multivariate model. The results are presented as regression coefficients that represent differences in cartilage volume per unit change in the relevant explanatory factor with other factors held constant. Second, Pearson's correlation coefficient test was used to investigate the correlation between the distal TGA and MR grading of patellar cartilage damage. A $p$ value of less than 0.05 indicated a statistically significant difference. Finally, the # statistic was used to assess inter-reader agreement in the interpretation of the cartilage damage. The degree of reader agreement was graded as follows: a # value of 0 - 0.20 indicated slight agreement; a # value of 0.21 - 0.40, fair agreement; a # value of 0.41 - 0.60, moderate agreement; a # value of 0.61 - 0.80, substantial agreement; and a # value of 0.81 - 1.00, almost perfect agreement.
Fig. 1: The distal trochlear groove angle (TGA) was measured from the most inferior slice image through the trochlear groove that was immediately prior to the level at which the medial and lateral condyles separate.

Fig. 2: The MR grading of patellar cartilage damage. Both observers classified as grade 2. The disruption of the surface lamina of the patellar cartilage is shown. The grade 2 lesion involved less than half of the articular cartilage thickness (arrow).

Fig. 3: The MR grading of patellar cartilage damage. Both observers classified as grade 3. The disruption of the surface lamina of the patellar cartilage is shown. Grade 3 indicated a cartilage defect involved more than half but less than the full thickness of the cartilage (arrow).

Fig. 4: The MR grading of patellar cartilage damage. Both observers classified as grade 4. The disruption of the surface lamina of the patellar cartilage is shown. Grade 4 indicated a cartilage defect involving the full thickness of the cartilage and exposed bone (arrow).

Results

The characteristics of the study subjects are presented in Table 2.

Table 2: Characteristics of Study Subjects

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 66)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>60.7 ± 15.2</td>
<td>26 - 86</td>
</tr>
<tr>
<td>Gender (% female)</td>
<td>66.7</td>
<td></td>
</tr>
<tr>
<td>Distal Trochlear Groove Angle (degree)</td>
<td>101.2 ± 5.9</td>
<td>83 - 116</td>
</tr>
<tr>
<td>Patellar Cartilage Volume (cm$^3$)</td>
<td>3.023 ± 0.236</td>
<td>1.908 - 3.665</td>
</tr>
<tr>
<td>Patellar Bone Volume (cm$^3$)</td>
<td>14.9 ± 3.3</td>
<td>9.4 - 24.8</td>
</tr>
<tr>
<td>Presence of Patellar Cartilage Damage (%)</td>
<td>65.2%† / 62.1%‡</td>
<td>0 - 4§</td>
</tr>
</tbody>
</table>

Note. - Data are mean ± standard deviation.

Percentage of patellar cartilage damage of medial facet: † Reader 1, ‡ Reader 2

§ Patellar cartilage damage were graded on MR images.

For every increase in the TGA at the distal femur, the patellar cartilage volume was significantly increased by $6.07 \times 10^{-3}$ cm$^3$ (95% confidence interval (CI): $1.27 \times 10^{-3}$, $10.9 \times 10^{-3}$) after adjustment for age, gender and patellar bone volume ($P < 0.05$) (Table 3, Fig 5).

Table 3: The Relationship between Distal Trochlear Groove Angle and Patellar Cartilage Volume

<table>
<thead>
<tr>
<th></th>
<th>Univariate Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartilage Volume ( (\text{cm}^3) )</td>
<td>Regression coefficient (95% CI)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td></td>
<td>( 7.00 \times 10^{-3} ) (( -2.92 \times 10^{-3}, 16.9 \times 10^{-3} ) )</td>
</tr>
</tbody>
</table>

**Multivariate Analyses**

<table>
<thead>
<tr>
<th>Cartilage Volume ( (\text{cm}^3) )</th>
<th>Regression coefficient (95% CI)</th>
<th>Pvalue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 6.07 \times 10^{-3} ) (( 1.27 \times 10^{-3}, 10.9 \times 10^{-3} ) ) ( $ )</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Note.- 95% CI = 95% confidence interval.

\( \$ \) Change patellar cartilage volume per degree increase in the angle at the trochlear groove after adjustment for age, gender and patellar bone volume in the regression equation.

The # values for the MR grading of patellar cartilage damage were 0.667 (95% CI: 0.529, 0.805) for the medial facet and 0.863 (95% CI: 0.721, 1.004) for lateral facet. This indicates substantial agreement for the medial facet and almost perfect agreement for the lateral facet. Reader 1 classified 23 patients as grade 0/1, 13 patients as grade 2, 18 patients as grade 3, and 12 patients as grade 4 in the medial facet. Reader 2 classified 25 patients as grade 0/1, 14 patients as grade 2, 17 patients as grade 3, and 10 patients as grade 4 in the medial facet. In contrast, both readers 1 and 2 classified 53 patients as grade 0/1, 3 patients as grade 2, 2 patients as grade 3, and 5 patients as grade 4 in the lateral facet. In the lateral facet, the number of patients with grade 0/1 was too large in relation to the patients with grade 2-4. Consequently, in the present study, the cartilage damage was evaluated only in the medial facet.

The relationship between the distal TGA and MR grading of the medial patellar cartilage damage is presented in Table 4. The MR grade of the patellar cartilage damage progressed as the distal TGA become narrower. However, there was no significant correlation between the distal TGA and the MR grading of patellar cartilage damage by the two readers.
Images for this section:

![Graph showing scatter plots and linear regressions between distal TGA and patellar cartilage volume.](image)

\[ y = 6.07 \times 10^{-3} x + 2.41 \]

distal TGA

patellar cartilage volume

**Fig. 5:** Scatter plots and linear regressions between distal TGA and patellar cartilage volume.

Conclusion

We have demonstrated that as the distal femoral trochlear groove becomes more flattened, there is an associated increase in the patellar cartilage volume. Our results concur with previous reports (5, 6).

In the present study, there was no significant correlation between the distal TGA and the MR grading of patellar cartilage damage, however, the patellar cartilage damage tended to progress as the distal TGA becomes narrower. This finding differs from those of previous investigators (5, 6, 10). Teichtahl et al. (8) reported that the degree increase in the distal TGA does not have a significant effect on the presence of cartilage defects among healthy adults. This discrepancy may be attributable to the differences in the patients' backgrounds. Davies-Tuck et al. (6) reported that there is no significant relationship between the TGA and the annual change in cartilage volume in an osteoarthritic population. This discrepancy may be attributable to the differences in the methods used to measure the TGA. They used skyline radiographs to measure the TGA; in contrast, we used MR imaging.

Kalichman et al. (10) demonstrated that a greater trochlear groove is associated with greater cartilage loss in symptomatic OA patients. However, in the present study, a greater TGA was associated with smaller cartilage loss. The difference in our findings and those of Kalichman et al. may be attributed to multiple factors. First, the methods used to measure the TGA were different. Their study had used the axial slice that referred to the proximal 1/3 of the femoral trochlear curve by using the 3D cursor on sagittal images. In the present study, the TGA were measured at defined levels at the distal aspects from axial images. The distal TGA was measured from the most inferior slice at which the medial and lateral condyles separate. Second, the evaluation method for cartilage morphology was different. Kalichman et al. used modified WORMS cartilage scores (10), while we used a previously published arthroscopy classification adapted to MR imaging (1, 7-9). We believe that a shallower femoral trochlear groove may have increased the articular contact area, which may reduce contact pressure. Therefore, a shallower, rather than a deeper, femoral trochlear groove may be better suited to reducing contact stresses.

In conclusion, we found that a more flattened distal TGA was associated with increased patellar cartilage volume. However, there was no association between TGA and patellar cartilage defects. Further longitudinal studies are required to examine the relationship between the TGA and patellar cartilage defects.
References


