The meniscofemoral ligaments during life and their morphometry in relation to the posterior cruciate ligament - an MRI analysis

Poster No.: C-2256
Congress: ECR 2015
Type: Scientific Exhibit
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Keywords: Anatomy, Musculoskeletal joint, Extremities, MR, Statistics, Normal variants, Epidemiology
DOI: 10.1594/ecr2015/C-2256

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Aims and objectives

The aims of this study were to display morphometric characteristics of the meniscofemoral ligaments (MFLs; anterior = aMFL, posterior = pMFL) in special reference to the posterior cruciate ligament (PCL) during different stages of life and to look for certain correlations between those structures.

The musculoskeletal system, including the MFLs, is subject to degeneration when growing older [1-3], therefore parameters of the MFLs were researched for changes in different age groups.

Parameters were also tested for differences between sexes, because many authors propose such differences for the MFLs [3-5] and other structures of the knee, like the anterior cruciate ligament (ACL), the PCL and the intercondylar roof [6-7].

Further, there are several ways in which the MFLs support the PCL [8-10], so special focus was laid on the correlation of the MFLs with the PCL.
Methods and materials

The retrospective study comprises knee MRIs of chosen **342 patients** out of 1880 regular patients from the Department of Radiology of the General Hospital Vienna, which were taken in the period from 2007-2012.

During the **selection process** patients were excluded if they had / were showing signs of:

- Arthroscopy or intraarticular surgery
- Rupture, lesion or degeneration of the cruciate ligaments
- Rupture, lesion or degeneration of the lateral meniscus
- Traumatic injury to the medial meniscus due to possible concomitant injury of other structures of the knee
- Arthritis of the knee
- Capsular damage of the knee
- Severe damage of the cartilage as occurring with gonarthrosis or osteochondritis dissecans
- Varus or valgus deformity of the knee
- Poor image quality

The patients were allocated to **five age groups** depending on their respective age at the date of examination:

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td># 10</td>
<td>18</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>11-20</td>
<td>20</td>
<td>33</td>
<td>53</td>
</tr>
<tr>
<td>21-30</td>
<td>43</td>
<td>52</td>
<td>95</td>
</tr>
<tr>
<td>31-45</td>
<td>42</td>
<td>53</td>
<td>95</td>
</tr>
<tr>
<td># 46</td>
<td>30</td>
<td>39</td>
<td>69</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>153</td>
<td>189</td>
<td>342</td>
</tr>
</tbody>
</table>

The range of the age groups was defined with consideration of the ossification of the femoral and tibial bone, body growth and alterations, which take place in advanced age [11-12]

All parameters were measured on MRI-images and statistically analyzed.

**Measuring**
**Length** After determining the presence or absence of the pMFL, the one coronal slice was chosen for measurement on which the pMFL's meniscal insertion and the length nearing its full extent were best visible. Then the length was measured from the point of separation at the meniscal insertion to the lateral wall of the medial femoral condyle. A similar approach was taken for the aMFL.

**Diameters and cross-sectional areas** According to other studies [5, 13] and to allow comparison of the results, the diameter of the MFLs was measured at the length's midpoint of the MFL in the sagittal plane. On the same images, the cross-sectional area of the MFLs was taken via an integrated area-measuring-tool.

The diameters and the cross-sectional area of the PCL were measured in the axial plane. On the level of the joint line the PCL was displayed as a hypointense, oval structure. The sagittal diameter was measured from the anterior to the posterior margin and at a right angle to this line the horizontal diameter was measured. On the same images, the cross-sectional area of the PCL was taken via an integrated area-measuring tool.

**Statistical analysis**

For every metric variable the mean, standard deviation and range were displayed. The normal distribution was tested with the Kolmogorov-Smirnov-Test, as well as visually through a Gaussian distribution curve over the histogram of the respective data. The homogeneity of variances was ensured through a non-significant Levene’s test. Correlations for metric data were tested via Pearson’s correlation coefficient. If no normal distribution was given, Spearman’s rank correlation coefficient was used instead.

For normally distributed, metric variables, differences between male and female subjects were tested for significance with Student's t-test. In the case of non-normally distributed, metric variables, the Mann-Whitney U-Test was used instead.

For categorical variables the Chi-Square-Test was used.

An Analysis of variance (ANOVA) was utilized to test for differences between the age-groups. To further locate the differences, post-hoc tests were used: Tukey’s test for variables with homogenous variances and the Games-Howell procedure for non-homogenous variances.

The alternative for an ANOVA in the event of non-normally distributed variables was the Kruskal-Wallis test with a follow-up of Mann-Whitney tests with a Bonferroni correction. p < 0.05 was considered as statistically significant.
Fig. 1: The right knee of a 26-year-old woman with the aMFL (arrows) seen on a coronal image as a hypointense band anteriorly to the PCL.

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**Fig. 2:** On this coronal image of the right knee of a 29-year-old woman the pMFL (arrows) can be seen as a straight-lined hypointense band posteriorly to the PCL.

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Fig. 3: The aMFL (arrows) appears as a hypointense dot-like or oval-shaped structure anteriorly to the PCL on sagittal images. The close relation between the aMFL and the PCL can be witnessed as the PCL bulges at the height of the aMFL.

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**Fig. 4:** The pMFL of a 21-year-old male seen on a sagittal image as a hypointense dot posteriorly to the pMFL.

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Results

- The incidence and morphometry of the MFLs doesn't vary significantly between sexes ($p > 0.05$).

- Above the age of 10 years, the prevalence of the MFLs doesn't vary significantly ($p > 0.05$).

- Length growth of the MFLs is concluded below the age of 11 years.

- The cross-sectional area of the MFLs increases until the age of 20 years and after this maintains constant values.

- The cross-sectional area of the PCL was significantly ($p < 0.05$) larger in knees with an absent pMFL ($Mdn = 39.7 \, \text{mm}^2$) than in knees with a present pMFL ($Mdn = 35.4 \, \text{mm}^2$) see Fig. 5.

- Single aMFLs ($Mdn = 4.5 \, \text{mm}^2$) had a significantly ($p < 0.0001$) larger cross-sectional area than aMFLs in knees with both MFLs ($Mdn = 1.8 \, \text{mm}^2$) see Fig. 6.

- Single pMFLs ($Mdn = 5.9 \, \text{mm}^2$) had a significantly ($p < 0.0001$) larger cross-sectional area than pMFLs in knees with both MFLs ($Mdn = 2.8 \, \text{mm}^2$) see Fig. 7.
Fig. 5: Influence of the presence of the pMFL on the cross-sectional area of the PCL. On average, the cross-sectional area of the PCL was larger in knees with an absent pMFL (Mdn = 39.7 mm²) than in knees with a present pMFL (Mdn = 35.4 mm²). This difference was significant $U = 9684.50$, $z = -2.36$, $p < 0.05$

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Fig. 6: Cross-sectional area of the aMFL in knees with a sole aMFL or both MFLs. Single aMFLs (Mdn = 4.5 mm²) had a significantly larger cross-sectional area than aMFLs in knees with both MFLs (Mdn = 1.8 mm²), U = 2929.5, z = -6.64, p < 0.0001

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**Fig. 7:** Cross-sectional area of the pMFL in knees with a sole pMFL or both MFLs. Single pMFLs (Mdn = 5.9 mm²) had a significantly larger cross-sectional area than pMFLs in knees with both MFLs (Mdn = 2.8 mm²), U = 3180, z = -6.18, p < 0.0001.

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Conclusion

The focus of this study, which is one of the largest of its kind, was to investigate the morphology of the MFLs to further elucidate possible roles of the MFLs in the knee joint.

Concerning the cross-sectional area, if there was only one MFL present, it was significantly larger than the same MFL in knees with both MFLs. This suggests a mechanism through which a missing MFL can be compensated by the other present and then thicker MFL.

Moreover, due to proposed synergy [8-9] of the MFLs and the PCL and their close proximity [10] this study tested the hypothesis of a larger cross-sectional area of the PCL if an MFL was missing. There was no difference in PCL-area in absence of the aMFL, however, if the pMFL was missing, the PCL-area was significantly larger than in knees with a present pMFL. The pMFL is considered the larger of the two MFLs [13-15] and to support the posteromedial bundle of the PCL synergistically [8]. Since the loading capacity of the posteromedial bundle reaches the one of the anterolateral bundle only partly [16-17], the PCL may have to compensate a missing pMFL by being thicker and therefore stronger, whereas in case of an absent aMFL the reserve capacity of the anterolateral bundle may suffice. Further biomechanical studies will be needed, before there can be a final conclusion.

One hypothesis was the degeneration of the MFLs during life, therefore patients with at least one missing MFL were supposed to be older than those with both MFLs present, as proposed by previous studies [2-3]. In this study, there was no significant difference regarding age and the presence of the MFLs, except for the age-group # 10 years, which was the only group, that showed more patients to have both MFLs present than to have at least one missing MFL.

Further, the comparison of age-groups 21-30 years and 31-45 years to # 46 years showed no difference in cross-sectional area for either the aMFL or the pMFL.

These results may be due to a low patient sample of > 60 year-olds and it is thinkable that excluding people with osteoarthritis of the knee, which affects up to 44% of elderly people [18], is the wrong approach and can cause a selection-bias. Since ruptured MFLs increase the femorotibial contact pressure [19-20] and increased femorotibial contact pressure leads to an increase in osteoarthritic changes in the knee joint [21], a correlation of missing or degenerated MFLs and osteoarthritis of the knee joint can be highly suspected.
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References


