The influence of the morphometric parameters of the intercondylar notch on occurrence of meniscofemoral ligaments

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Background: The purpose of this study was to examine the existence of correlation between the morphometric parameters of the intercondylar notch of the femur and the occurrence of meniscofemoral ligaments (MFLs) and if there is any relationship in the running angle (RA) value between narrowed and normal sized intercondylar notch.

Materials and methods: Coronal, sagittal and horizontal magnetic resonance (MR) images of 90 patients with specified exclusion criteria were included in this study. The χ² test was used for statistical analysis. In our research either one or both MFLs were identified in 70 (77.8%) of the 90 coronal MR images. In normal sized intercondylar notch, MFLs was seen in 39 (43.3%) cases and on 31 (34.4%) MR images with narrowed intercondylar notch.

Results: A significant correlation was established between the occurrence of the MFL and morphometric parameters of the intercondylar notch (p < 0.05). In normal sized intercondylar notch, 12 posterior meniscofemoral ligaments (pMFLs) of type I were detected (RA value 42°), 8 of type II (RA value 33°), 5 of type III (RA value 23°) and two were of indeterminate type, whilst 10 anterior meniscofemoral ligaments (aMFLs) were of type I (RA value 39°), 7 of type II (RA value 31°), 2 of type III (RA value 25°) and the remaining 6 were indeterminate. In narrowed intercondylar notch, 10 ligaments of pMFLs were of type I (RA value 30°), 8 of type II (RA value 25°), 5 of type III (RA value 20°), 10 ligaments of aMFLs were of type I (RA value 35°) and 9 were indeterminate. Statistically significant differences in the value of the running angle of pMFL type I and of type II were evaluated between two groups with different shaped intercondylar notch (p < 0.05).

Conclusions: The results shown in our study may be useful in medical clinical practice, reconstructive surgery, interpretation of knee MR images as well as genetic research. (Folia Morphol 2022; 81, 1: 190–195)

Key words: intercondylar notch, meniscofemoral ligament, knee and magnetic resonance
INTRODUCTION

The intercondylar notch (IN) is located on the posterior side of the distal part of the femur between the lateral and medial condyle. The roof of the notch is built by the distal extremity of the femur while its distal and posterior borders are marked by distal surface of condyles [20]. Anderson et al. [4] found that the females have a smaller IN dimensions compared to males but they found no difference in shape of the notch. Based on morphometric parameters of IN, Hutchinson et al. [14] defined two types of IN, U-shaped and A-shaped notch, while Tanzer and Lenczner [21] considered narrowed IN, as A-shaped and IN with normal with as U-shaped notch.

The variation in morphology of the femur is associated with increased risk for ligament injury. Of the ligaments in the knee joint, the anterior cruciate ligament (ACL) is the most commonly injured [19, 20, 25]. Intercondylar notch dimensions are considered as a significant predictive risk factor for ACL injury [5]. The meniscofemoral ligaments (MFLs) connect the posterior horn of the lateral meniscus to the intercondylar aspect of the medial femoral condyle, or to the posterior cruciate ligament [23]. There are two types of MFLs, depending on their position in relation to the posterior cruciate ligament (PCL). According to Amis et al. [1] the ligament of Humphry (anterior meniscofemoral ligament [aMFL]) passes anterior to the PCL and attaches distally, close to the articular cartilage. The ligament of Wrisberg (posterior meniscofemoral ligament [pMFL]) passes posterior to the PCL and attaches proximally, close to the roof of the IN [1, 2]. The aMFL is tense in knee flexion, while the pMFL is tense in knee extension. [9]. One MFL is present in 93% of specimens, whilst both ligaments co-exist more frequently in younger specimens [10, 11, 24]. According to earlier anatomical studies their incidence may range from 35% to 76% [12]. The attachments of those two ligaments are separated, which supports the theory that those are two separate structures and not, as was previously thought, two branches of the same ligament [15]. The other study suggests that they may degenerate with age [18]. It has previously been demonstrated that additional resection of the MFL further destabilised the knee joint, as well as significantly increased anterior tibial translation [8, 17].

In literature data, depending on the location of the attachment, there are three types of MFLs: 1) the ligament of type I, inserted into the medial femoral condyle and separated from the PCL; 2) the ligament of type II, attached to the proximal portion of the PCL; 3) the ligament of type III, attached to the distal portion of the PCL [7]. Cho et al. [7] defined the running angle of the MFL as the angle between the line connecting the distal surfaces of medial and lateral femoral condyles and the long axis of the MFL. The relationship between morphometric parameters of the IN and the running angle value was reported [7]. However, the influence of the morphometric parameters of the IN on the value of the running angle is poorly described in literature. On the other hand, this information could be relevant in predicting the risk of MFLs rupture and their degeneration.

The aim of this study was to determinate occurrence of MFLs depending on the IN morphometry, to examine incidence of single and both MFLs as well the absence of MFLs, to evaluate statistically significant difference between the different type of IN and finally to determinate influence of its morphology on the value of the running angle.

MATERIALS AND METHODS

The study included magnetic resonance (MR) images of 90 patients (48 males and 42 females), aged from 20 to 60 (44.68 ± 10.52) receiving a 1.5-T knee scan at our radiologic institute after the approval from ethics committee, which were taken in the period from 2010 to 2017. All MR examinations were performed on 1.5-T MR unit (Siemens Area AG, model syngo MR E11, with NUMARIS/4 software, Siemens software packages). The knee was placed in neutral position in an extremity coil. Coronal images were obtained using conventional spin-echo techniques (time to echo: 8.7 ms, repetition time: 3080 ms, field of view: 190 × 190 mm, section thickness: 3.5 mm, with 1 mm gap, voxel size: 0.6 × 0.6 × 3.5 mm). Additionally, for the measurements, we used ImageJ 1.50 g software (National Institutes of Health, USA). The following exclusion criteria were defined:
— inadequate quality of the images;
— fracture or dysplasia of the distal femur;
— previous arthroscopy or open surgery;
— osteoarthritic changes of the IN;
— varus or valgus deformity of the knee.

The following parameters on horizontal images (Fig. 1) were measured: the width of the lateral and medial femoral condyle, the notch width (NW), the total width of the distal femur. The cross section (a) on which measurements were conducted was determined on sagittal MR images, based on the vertical
line (h) which passes through the most posterior
point of the lateral and medial condyle (Fig. 2). At
this level, on axial images, the measurements were
done on the line which passes through the popliteal
groove. The width of the medial femoral condyle (b)
and the width of the lateral femoral condyle (c) were
measured as the distance between the external and
internal margins of each condyle and the NW was
measured as the distance between the inner most
margins of femoral condyles (a). Also, the notch
height (ICH) was measured on the line perpendicular
to the line constructed through the most posterior
point of the lateral and medial condyle of the femur,
as a distance between the apex of the IN and the
intersection of above mentioned lines (h) (Fig. 1).

The notch width index (NWI) — the ratio between
the NW and the total width of the distal femur, was
calculated. The values of the NWI of 0.270 or more
were considered as normal, while values of 0.269
or less were considered as below normal [3]. Notch
shape index (NSI) was defined as the ratio between
the NW and the ICH. The values of the NSI of 0.532
or less indicate on stenosed type of the IN [22]. We
measured the running angle of the MFL as the angle
between the line connecting the distal surfaces of
medial and lateral femoral condyles and the long
axis of the MFL on coronal images, using in literature
described method (Fig. 3) [7]. Authors have noted
no significant difference in the value of the running
angle between the ligament of Humphery and the
ligament of Wrisberg [7], so we used these criteria
for both ligaments.

All measurements were done by two independent
investigators. No significant difference was found in
comparison of their measurements. In order to avoid
bias, the measurements were repeated by both exam-
iners after 3 weeks on the same, randomly selected
50 MR images. The results were compared by Cohen
kappa coefficient, with kappa values over the 0.8 for
all measurement, which suggest very good intra- and
interobserver agreement.

Statistical analysis
The statistical differences between the pres-
ence and absence MFLs as well as prevalence of
A- or U-shaped IN on MR images were evaluated by
\( \chi^2 \) tests. A p value of less than 0.05 was regarded as
statistically significant.

For every metric variable the mean, standard de-
viation and range were displayed. The normal dis-
tribution was tested with the Kolmogorov-Smirnov
test, as well as visually through a Gaussian distribu-
tion curve over the histogram of the respective data.
The homogeneity of variances was ensured through
a non-significant Levene’s test. For normally distribut-
ed, metric variables, differences between the groups
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.

**RESULTS**

According to NWI and NSI criteria we found U-shaped IN in 46 (51.2%) analysed coronal MR images and A-shaped IN in 44 (48.8%) (Table 1). There was no significant difference in incidence between the groups (p > 0.05). The MFLs was identified in 70 (77.8%) of the 90 coronal MR images scans. In group with U-shaped IN, MFLs was observed in 39 (43.3%) cases and in 31 (34.4%) cases in the group with A-shaped IN. There was a significant difference in MFLs occurrence between the groups with A- and U-shaped IN (p < 0.05).

**U-shaped.** The pMFL was seen alone in 30.4% (14) of cases, while aMFL was observed alone in 26.1% (12). Both ligaments were visible in 28.3% (13) while neither was found in 15.2% (7) cases. Among the pMFL, 12 ligaments were of type I (average running angle [RA] value 42°), 8 of type II (average RA value 33°), 5 of type III (average RA value 23°) and 2 were classified as indeterminate type, whilst 10 ligaments of aMFL were of type I (average RA value 39°), 7 of type II (average RA value 31°), 2 of type III (average RA value 25°) and the remaining 6 were indeterminate. Statistically significant difference in the value of the RA was observed between the types (p < 0.05). No significant differences in the value of the RA between the pMFL and aMFL were noted (p > 0.05).

**A-shaped.** In A-shaped IN single pMFL was detected in 27.3% (12) of cases and the single aMFL ligament was observed in 18.2% (8). Both ligaments were found in 25% (11) while neither was found in 29.5% (13). Statistically significant difference in the MFLs not detected group was observed between the A and U form of IN (p < 0.05). Among the pMFLs, 10 ligaments were of type I (average RA value 30°), 8 of type II (average RA value 25°), 5 of type III (average RA value 20°), while 10 ligaments of aMFLs were of type I (average RA value 35°) and 9 were indeterminate. Statistically significant differences in the value of the running angle were noted between the type I and type II (p < 0.05).

### Table 1. Mean magnetic resonance images measurements of the distal femur

|                      | Intercondylar notch width [mm] | Intercondylar notch height [mm] | Total width of distal femur [mm] | Notch shape index | Notch width index |
|----------------------|--------------------------------|--------------------------------|----------------------------------|------------------|------------------|
| U-shaped             | 21.23 ± 2.28                   | 36.77 ± 1.67                   | 76.27 ± 7.10                     | 0.577 ± 0.021    | 0.278 ± 0.023    |
| A-shaped             | 19.98 ± 1.75                   | 37.95 ± 1.43                   | 76.45 ± 6.23                     | 0.526 ± 0.018    | 0.261 ± 0.012    |

**Figure 3. A.** Coronal magnetic resonance image shows the meniscofemoral ligament (arrow); **B.** The running angle of the meniscofemoral ligament as the angle between the distal surfaces of medial and lateral condyles and long axis of the meniscofemoral ligament on coronal magnetic resonance images.
Statistically significant differences in the value of the running angle of pMFL type I, between U- and A-shaped IN was observed (p < 0.05, Table 2).

DISCUSSION

Earlier studies of the MFLs pointed different incidence of the aMFL and pMFL. The differences can be also found between the MR images and cadaveric studies. Herzog et al. [13] found that the MR images measurements were the closest to directly measured in the cadaver. Gupte et al. [10] conducted MR images study in which 93% specimens contained at least one MFL. The aMFL was present in 74%, and the pMFL in 69%. Both ligaments were present in 50%. Bintoudi et al. [6] found the MFLs in 37% of cases, while in 7.6% of cases MFLs were absent. In MR imaging performed by Cho et al. [7] the pMFL was identified in 90% of cases and aMFL was observed in 17%. Both ligaments were visible in 15% cases and neither was seen in 7.5%. Kusayama et al. [16] showed the MFL with incidences of 100% and that 46% of the specimens had both MFLs, 23% had only aMFL and the remaining 31% had a pMFL. Röhrich et al. [18] reported that the MFL exists in incidences of 94%, aMFL in incidences of 71% as was the incidence of pMFL (71%) and both MFLs was seen in 47% cases. The incidence of pMFL was higher than incidence of aMFL in most MR imaging studies. In anatomical studies in the literature, incidences range from 35% to 76% for the presence of at least one MFL [12].

In accordance with other authors, we found MFLs in 70 coronal MR images (77.8%), only aMFL was observed in 20.3% of cases, pMFL in 37.14%, both ligaments were present in 34.2% while in 20.3% MFLs was absent. The results presented in this paper are totally in agreement to the findings of the most studies. However, the authors showed incidence of MFL independent of IN morphology. In our MR images study, we created two IN groups, according to NWI and NSI criteria, U- and A-shaped notch group. In group with U-shaped IN, we observed at least one MFL with incidence of 84%, while in A-shaped IN group incidence was 70.4%. Occurrence of MFLs obtained in our study is lower in narrowed notch compared with normal sized notch. This probably demonstrates that anatomical changes in this region could have an influence on development and anatomical characteristic of these ligaments. Because of the limitation of the resolution of MR imaging, 15 of the 44 aMFLs, and 2 of the 50 pMFLs did not present details at MR imaging. Similar misreading was noted in literature data [7]. The report of Cho et al. [7] showed that the average running angle was 35° in the type I, 30° in the type II and 27° in the type III. In our study, the average running angle was a little higher in the normal sized IN. The lower value of the running angle in A-shaped IN may be explained by descending medial IN wall, combined with lower ligaments attachment [25]. Statistically significant difference was found in the value of the running angle of pMFL type I, between U- and A-shaped IN. The running angle modification may be associated with narrowing of the IN, so further studies are needed to investigate this correlation.

CONCLUSIONS

After conducting the research, we found significant correlation between the IN morphology and presence or absence of the MFLs as well as the running angle value. The data obtained in our study may be useful in medical clinical practice (reconstructive surgery), interpretation of knee MR images or genetic

**Table 2. Incidence of the meniscofemoral ligaments (MFLs) and the values of its running angle (RA) in U-shaped and A-shaped intercondylar notch (IN)**

| Ligament (n) | U (n) | A (n) | U-shaped IN | A-shaped IN | P |
|--------------|-------|-------|-------------|-------------|---|
| Posterior MFL (50) | 27 | 23 | Type I (12) 42 ± 3.9 | Type I (10) 30° ± 2.6 | p < 0.05* |
| | | | Type II (8) 33 ± 2.3 | Type II (8) 25° ± 2.2 | p < 0.05* |
| | | | Type III (5) 23 ± 2.5 | Type III (5) 20° ± 1.6 | p > 0.05 |
| | | | ID type (2) – | ID type (2) – | – |
| Anterior MFL (44) | 25 | 19 | Type I (10) 39 ± 2.7 | Type I (10) 35° ± 2.5 | p > 0.05 |
| | | | Type II (7) 31 ± 2.5 | Type II (1) – | – |
| | | | Type III (2) 25 ± 1.2 | Type III (1) – | – |
| | | | ID type (6) – | ID type (9) – | – |

*Statistically significant difference; U — normal sized intercondylar notch; A — narrowed intercondylar notch; ID — indeterminate type of MFL.
research. Our results suggest that it is possible to determine which patient have narrower IN based on the running angle value. Further study is needed to determine if a correlation exists between morphometry of IN and the value of the running angle.

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