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Cadaveric-Biomechanical study on medial retinaculum: Its stabilising role for the patella against lateral dislocation

Short title: Medial retinaculum and patella dislocation

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Abstract

Background: The aim of this study was to analyse the biomechanical role of medial retinaculum, as a stabilising factor against lateral patellar dislocation.

Materials and methods: This cadaveric-biomechanical study included the patellae of ten cadaveric knees, which were surgically exposed and the medial retinaculum of each one was located. A stable 24.51N force was applied to the four parts of the quadriceps, and an increasing lateral displacing force was applied to the patella, up to 5mm dislocation. The study was repeated for 0⁰, 45⁰, and 90⁰ of knee flexion, with the medial retinaculum intact and dissected. The Wilcoxon signed rank test was used for data analysis. A p value <0.05 was considered as statistical significant.

Results: After the dissection of medial retinaculum, the lateral displacement force was lower at every angle of knee flexion (p=0.005, p=0.007, p=0.005 respectively). The lateral displacement force increased as the flexion angle increased (p=0.005), regardless of medial retinaculum integrity.

Conclusions: Medial retinaculum acts as a stabilising factor for the patella, against its lateral dislocation in lower flexion angles. Therefore, methods of surgical
reinforcement or repair of medial retinaculum could provide protection against recurrent patellar dislocation.

**Key words:** patellar instability, patellar retinaculum, medial stabilisers, lateral displacement force, medial patellofemoral ligament

**Introduction**

Patellar dislocation is a common occurrence in children and adolescents, characterized by lateral dislocation of the patella, usually followed by spontaneous reduction. During patella dislocation, soft-tissue structures, such as the medial patellofemoral ligament (MPFL), medial retinaculum (MR) and vastus medialis obliquus (VMO) muscle fibers, are usually injured, frequently leading to recurrent dislocations (9).

Dislocation which occurs for the first time is usually treated conservatively, with some exceptions, such as in the presence of osteochondral fragments or important soft tissue damage (7). Recurrent and chronic dislocations are usually treated by medial structure repair. Most common procedures include reconstruction of the medial patellofemoral ligament, reinforcement of the medial retinaculum, with or without lateral release, medialization of the insertion of the patellar ligament, trochleoplasty, and tibial tubercle-trochlear groove (TT-TG) distance change (7).

As far as the MPFL is concerned, cadaveric studies showed a contribution of up to 50-60% to the stability of the patella (5, 13). Other stabilising structures are the medial patellomenisceal ligament (MPML) and the medial patellotibial ligament (MPTL) (13), plus the medial retinaculum, which was the main subject of our study.

There are many studies in the literature proposing methods of surgical reinforcement of the medial retinaculum, such as medial retinaculum reefing (1), plasty (8), imbrication (16), plication (21), thermal shrinkage (2), whether arthroscopic (3, 14, 15, 18) or not. In most studies the outcomes were positive, showing that the medial retinaculum plays an important role as a stabilising factor for the patella. There have also been studies comparing methods of medial retinaculum repair and repair of other medial stabilisers, such as the vastus medialis (20) and medial patellofemoral ligament (21), showing that MPFL is a better static stabiliser compared to MR. Studies dealing with MPFL repair alone also showed good clinical results, reinforcing the view that MPFL is the main stabiliser against lateral
displacement of the patella (4, 5, 10, 11, 12, 17, 19), especially in lower angles of flexion.

The main objective of this cadaveric study was to evaluate the contribution of the medial retinaculum as a lateral patellar stabiliser for the knee. The study hypothesis was that the medial retinaculum provides adequate stability against lateral displacement forces, when intact.

According to the above-mentioned literature, surgical interventions reinforcing the medial retinaculum yield good outcomes in terms of the lateral stability of the patella, in cases of recurrent patella dislocation. These methods can usually be performed arthroscopically, which is quite important regarding the surgical complications. With this cadaveric biomechanical study, we tried to show that an intact medial retinaculum is important for the stability of the patella, especially against lateral displacement forces, thereby making a contribution to the current literature.

**Materials and methods**

The patellae and surrounding soft tissues of ten frozen cadaveric knees, with no known previous pathology or anatomical variation, were surgically exposed, using an incision across the two poles of the patella, extended proximally and distally by 5cm. The MPFL and MR were identified and marked using a coloured marker. The center of the patella was located and marked using a coloured stitch, while an ethibond stitch was attached to the lateral and middle sides of the soft tissue surrounding the patella. Finally, four ethibond stitches were attached and clothed around the mass of the four parts of the quadriceps muscle (Rectus femoris, vastus medialis, vastus lateralis, vastus intermedius) (Figure 1).

Each knee was then placed on the study table, with the lateral side of the patella facing upwards. So, it was possible to flex and extend the knee and the degrees of flexion could be monitored using a goniometer, on the table.

The other end of the stitch attached to the lateral-middle side of the patella, was then rolled over a rod above and parallel to the table surface, and was finally attached to a dynamometer. The ends of the four stitches attached to the quadriceps muscle were attached to weights, hanging out and below the study table (Figure 2). So, a 24.51N (2.5kg) force was constantly applied to the patella through the quadriceps muscle and tendon, partially simulating the stabilising forces applied to the patella by
quadriceps in vivo. Finally, a numbered ruler was placed next to the marked patella center, for measuring the patella’s lateral displacement.

In this study table setup, we measured the forces that displaced the patella laterally by 5mm (lateral displacement force), in six distinct cases: with the medial retinaculum intact with knee flexed to 0, 45 and 90 degrees and with the medial retinaculum dissected with knee flexed to 0, 45 and 90 degrees.

**Statistical analysis**

The data collected was statistically analysed using the non-parametric Wilcoxon signed rank test (SPSS, version 23, Chicago, USA for OsX), due to paired data and small sample size. The Kolmogorov-Smirnov test of normality was also used to ensure whether the data were normally distributed. A p value <0.05 was considered as statistical significant. The confidence interval was 95%.

**Ethical approval**

This study was conducted after approval by the Medical Research Ethics Committee of the Faculty of Medicine, University of Ioannina, Ioannina, Greece.

**Results**

As shown in Tables 1 and 2, after statistical analysis of the data, the lateral displacement force applied to the patella was lower after the dissection of the medial retinaculum at 0, 45 and 90 degrees of flexion. In detail, at 0 degrees the p value was 0.005, at 45 degrees p value was 0.007 and finally at 90 degrees p value was 0.005.

We also noticed that the lateral displacement force was higher with increasing flexion angles for the knee (p value=0.005), regardless of medial retinaculum integrity.

The above-mentioned p values, being statistically significant, reinforced our hypothesis that an intact medial retinaculum provides adequate stability against lateral displacing forces to the patella, especially at lower angles of flexion of the knee.

**Discussion**

The statistical verification of our hypothesis leads to the conclusion that the
medial retinaculum plays an important role as a medial stabiliser of the patella, especially in low angles of flexion, since from 20 to 90 degrees of knee flexion, the interaction of bones is an additional contribution to the stability of the patella, which is in concordance with the literature (6, 13). The MPFL and MPML are major stabilisers, contributing up to 50-60% and 24% respectively, while MR and MPTL contributes up to 13% (5, 13). VMO also plays an important role, specially in the first 20-30 degrees of flexion, due to the meshing of its fibers to MPFL, reinforcing MPFLs stabilising role(13).

Warren and Marshall in 1979 described the anatomy of the medial stabilisers of the knee in detail, documenting three layers of soft tissue (17). The main components of the medial side of the knee are the MPFL, MPML, MPTL and MR (Figure 3, 4, 5). MPFL originates from the medial femoral epicondyle and inserts to the medial side of the patella, between layers I and II. Its fibers mesh with MR fibers. MPML originates from medial capsulo-meniscal region and inserts to the lower patellar pole. MPTL originates from the medial side of the tibia, 1.5-2 cm below the joint and 1.5-2 cm medial to the patellar tendon and inserts to the lower pole of the patella. Its fibers mesh with MR fibers as well. MR fibers come from the deep or crural fascia (layer I: the first facial plane found after a skin incision), the vastus medialis tendon and the quadriceps. MR can be identified in front of the medial collateral ligament (MCL) and meets the patellar tendon. It constitutes layers I and II by Warren and Marshall (13, 17).

Other anatomic factors contributing to the stability of the patella are the interaction of the bones, such as the patella and the trochlear groove, especially in flexed knees (after 20 degrees), which changes in cases of a shallow groove or patella alta and baja. The interaction of the quadriceps muscle and the patella, through the force applied to the patella by the muscle (Q-angle), is also an important factor for the stability of the patella.

On the basis of the above, we used ten cadaveric knees with no known anatomical variations or previous pathology. Our anatomic dissection findings were in concordance with the literature (13, 17). Despite this, we should note some experimental limitations: the stabilising force applied by the quadriceps muscle to the patella is greater in vivo than in our study, due to the tearing of the cadaver muscle fibers, when force was applied to the muscle, by the ethibond stitches. In vivo, the surrounding tissues apply additional force to the patella, when a human body is in a
standing position or in several other states, such as running and jumping. So, the contribution of bone to bone contact and muscle to the stability of the patella is not comparable to in vivo cases.

Despite these limitations, this study quantified the lateral displacement force to the patella, preserving and dissecting the medial retinaculum and supported the hypothesis that MR plays an important role as a stabiliser against patella lateral dislocation.

Conclusions

Although MPFL is the main stabiliser against lateral patellar dislocation and the most common surgical interventions consist of repair or reinforcement of this structure, surgical methods to reinforce the medial retinaculum, combined or not with methods of relaxation of the lateral soft tissues and anatomical modifications, are important for the treatment of recurrent patella dislocations. So despite the fact that further studies should be conducted on medial patella stabilisers and especially MR, we believe that the surgeons should put in their plan the repair or reinforcement of this structure.

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Authors’ contributions

Conception and design: LM and PK. Acquisition, analysis and interpretation of data: LM, AB, PK, GP, AK, GM, PK. Drafting the article: LM, AB, PK, GP, AK, GM, PK. Revising it critically for important intellectual content: LM, PK. Approved final version of the manuscript: LM, AB, PK, GP, AK, GM, PK.

Conflict of interest

The authors declare that they have no conflict of interest.

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Table I: Measurement results

Table II: Data graph

Figure 1: The quadriceps parts and medial structures of the knee: Rectus femoris, Vastus medialis, Vastus lateralis, Vastus intermedius (deeper to rectus femoris), Medial collateral ligament (MCL), Medial retinaculum (MR)

Figure 2: Study table setup

Figure 3: Medial patellofemoral ligament (MPFL), Medial patellomenisceal ligament (MPML), Medial patellotibial ligament (MPTL), Medial retinaculum (MR), Vastus medialis obliquus (VMO), Rectus femoris (RF), Medial collateral ligament (MCL)

Figure 4: Medial patellofemoral ligament (Cadaver)

Figure 5: Medial retinaculum (Cadaver)
### Table 1: Measurement results

|                | INTACT-EXTENSION | INTACT-45 FLEXION | INTACT-90 FLEXION | DISSECTED-EXTENSION | DISSECTED-45 FLEXION | DISSECTED-90 FLEXION |
|----------------|------------------|-------------------|-------------------|---------------------|----------------------|----------------------|
| Knee No 1      | 4.13 N           | 6.99 N            | 13.18 N           | 3.04 N              | 6.36 N               | 8.92 N               |
| Knee No 2      | 3.55 N           | 4.43 N            | 9.27 N            | 2.62 N              | 3.55 N               | 9.02 N               |
| Knee No 3      | 3.13 N           | 3.99 N            | 10.80 N           | 1.87 N              | 3.39 N               | 8.88 N               |
| Knee No 4      | 1.67 N           | 4.41 N            | 7.93 N            | 1.01 N              | 2.78 N               | 7.89 N               |
| Knee No 5      | 2.18 N           | 3.90 N            | 9.42 N            | 1.20 N              | 2.94 N               | 8.71 N               |
| Knee No 6      | 3.14 N           | 4.24 N            | 9.83 N            | 2.14 N              | 4.68 N               | 9.12 N               |
| Knee No 7      | 4.22 N           | 6.02 N            | 9.88 N            | 3.06 N              | 5.42 N               | 9.11 N               |
| Knee No 8      | 4.16 N           | 6.34 N            | 9.04 N            | 3.20 N              | 5.38 N               | 8.70 N               |
| Knee No 9      | 2.67 N           | 4.01 N            | 8.99 N            | 1.39 N              | 3.01 N               | 8.10 N               |
| Knee No 10     | 3.02 N           | 4.20 N            | 8.90 N            | 1.70 N              | 3.23 N               | 8.12 N               |
Table 2: Data Graph (Mean with SE)

Comparison between knees:
1) Intact retinaculum – Knee extended to Dissected retinaculum – Knee extended, P value=0.005
2) Intact retinaculum – Knee 45 degrees flexion to Dissected retinaculum – Knee 45 degrees flexion, P value=0.007
3) Intact retinaculum – Knee 90 degrees flexion to Dissected retinaculum – Knee 90 degrees flexion, P value=0.005
Medial retinaculum