Recurrence lateral patellar dislocation is noted to occur in approximately 44% to 71% of patients treated nonoperatively following primary dislocation.1-5 The medial patellofemoral ligament (MPFL) is the primary soft tissue restraint to lateral translation of the patella and is considered the “essential lesion” of patellar dislocation.6,7 Previous studies have reported injury to the MPFL in 95% to 100% of patients following acute dislocation.8-10 This has led to an increased interest in repair or reconstruction of the MPFL for patients experiencing recurrent instability. The femoral attachment of the MPFL is critical in determining graft behavior following reconstruction. The femoral attachment can be determined by referencing local anatomy, fluoroscopic imaging or on the basis of desired graft-length changes. This article reviews the anatomy of the MPFL, with a focus on its femoral insertion site as it pertains to anatomic, isometric, and anisometric reconstruction. [Orthopedics. 2017; 40(4):e583-e588.]

The Anatomy of the Medial Patellofemoral Ligament

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abstract

Recurrence lateral patellar dislocation is observed in many patients treated nonoperatively following primary dislocation. Injury to the medial patellofemoral ligament (MPFL) is reported in the majority of patients following dislocation. There is an increased interest in repair or reconstruction of the MPFL for patients experiencing recurrent instability. The femoral attachment of the MPFL is critical in determining graft behavior following reconstruction. The femoral attachment can be determined by referencing local anatomy, fluoroscopic imaging or on the basis of desired graft-length changes. This article reviews the anatomy of the MPFL, with a focus on its femoral insertion site as it pertains to anatomic, isometric, and anisometric reconstruction. [Orthopedics. 2017; 40(4):e583-e588.]

ANATOMY

Understanding of the femoral insertion point of the MPFL continues to evolve. Previous studies of the femoral insertion point have described varying relationships with the medial epicondyle, adductor tubercle, medial collateral ligament (MCL), posteromedial capsule, and adductor magnus tendon.6,8,9,11,14-19 In general, the MPFL spans from the area containing the medial epicondyle to the superior one-third or one-half of the medial border of the patella.20 Feller et al16 dissected 20 cadaveric knees and described the MPFL attaching to the femur along the anterior aspect of the medial epicondyle. In contrast, Tuxoe et al9 described the femoral origin arising distal to the adductor magnus tendon along the anterior aspect of the adductor tubercle in 39 cadaveric knees. Superficial fibers of the MPFL were noted to arise from the posteromedial capsule in 100% of knees, while a portion of the distal fibers joined the MCL in 82% of knees.9

Smirk and Morris21 evaluated 25 cadaveric knees and noted the femoral attachment of the MPFL was most commonly observed along the posterior aspect of the medial epicondyle (84%), approximately 1 cm distal to the adductor tubercle. Forty-four percent of knees possessed an isolated MPFL attachment site. The remaining knees possessed a wider attachment site that included the femoral origin of the MCL.

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attachment site including an area posterior to the adductor magnus tendon (20%), the adductor magnus tendon itself (12%), the adductor tubercle (4%), or a combination of all three (4%). The remaining 4 knees (16%) had an attachment anterior to the medial epicondyle. In contrast, Steensen et al\textsuperscript{19} noted the femoral attachment as the entire length of the anterior aspect of the medial epicondyle, with the inferior portion of the MPFL and the superior portion of the MCL in direct contact in 100% of knees.

Nomura et al\textsuperscript{14} recognized some controversy by identifying the MPFL femoral attachment superoposterior to the medial epicondyle just distal to the adductor tubercle in 20 knees. Superficial fibers extended to the posteromedial capsule, while the deep fibers inserted directly onto bone in all knees. Variable insertions onto the superficial MCL were also identified in 50% of knees.\textsuperscript{14} Contrary to the study by Smirk and Morris,\textsuperscript{21} the MPFL was not observed to insert onto the adductor magnus tendon.\textsuperscript{14} LaPrade et al\textsuperscript{18} (8 knees) and Philippot et al\textsuperscript{15} (23 knees) both described the femoral attachment proximal and posterior to the medial epicondyle between the adductor magnus tendon and the superficial MCL. Philippot et al\textsuperscript{15} also reported a strong relationship between the MPFL and MCL in 40% of knees, similar to the findings reported by Steensen et al\textsuperscript{19} and Nomura et al\textsuperscript{14}. No specimens possessed insertions onto either the posteromedial capsule or the adductor magnus tendon.\textsuperscript{15} Fujino et al\textsuperscript{10} documented the femoral insertion of the MPFL 10 mm distal to the adductor tubercle along the long axis of the femur in 31 cadaveric knees using a combination of gross pathology and 3-dimensional computed tomography reconstructions. The insertion area of the MPFL occupied approximately 56.5±169 mm\textsuperscript{2} in that study.\textsuperscript{10}

Two studies\textsuperscript{17,20} described the MPFL as the confluence of 2 independent bundles. Baldwin\textsuperscript{20} evaluated 50 cadaveric knees and described 2 independent femoral origins. One was a transverse origin from a bony groove between the medial epicondyle and the adductor tubercle. The other was an oblique decussation from the leading edge of the superficial MCL. Kang et al\textsuperscript{17} however, described “functional bundles” with a common origin distal to the adductor magnus tendon and proximal to the MCL attachment. These bundles, termed the inferior straight and short oblique bundles, inserted onto the superior and middle portions of the patella, respectively.\textsuperscript{17}

On the basis of these studies, there appears to be some variability in the femoral attachment site of the MPFL (Table). Although authors generally agree that the femoral attachment site can be found near the medial epicondyle (Figure 1), variability exists in the insertion area as well as the ligament’s relationship with the adductor tubercle, MCL, posteromedial capsule, and adductor magnus tendon. It is unknown how these relationships affect the function of the MPFL in both normal knees and those of patients with recurrent patellar instability.

**Radiologic Evaluation**

Radiographic landmarks have been described to assist intraoperative placement of the femoral attachment during MPFL reconstruction (Figure 2).\textsuperscript{22} In a 2007 cadaveric study of 8 knees, Schöttle et al\textsuperscript{22} reported that the radiographic origin of the MPFL could be identified on a lateral radiograph of the knee 1 mm anterior to an extension of the posterior cortical line and 2.5 mm distal to a perpendicular line intersecting the posterior origin of the medial femoral condyle. Using these radiographic landmarks, Redfern et al\textsuperscript{23} argued that the point of intersection described by Schöttle et al\textsuperscript{22} consistently placed the femoral origin anterior and distal (2.5 mm and 0.6 mm, respectively) to that of the native MPFL. The authors\textsuperscript{23} suggested that a femoral attachment placed more posteriorly (0.5 mm anterior to the posterior femoral cortical line and 3 mm proximal to a perpendicular line that intersects the posterior aspect of Blumensaat’s line) may more closely replicate the anatomy of the native MPFL.

Wijdicks et al\textsuperscript{24} found the attachment 8.9 mm distal and anterior from the adductor tubercle on lateral radiographs of 11 knees. They reported that the radiographic landmark of the femoral origin was located in the anterior-proximal quadrant formed by an extension of the posterior cortical line and a horizontal line that intersects the posterior aspect of Blumensaat’s line. A high rate of inter- and intraobserver reliability was reported using this method for femoral tunnel placement. Despite using a similar quadrant referencing system, Barnett et al\textsuperscript{25} found the native MPFL femoral insertion to be only 3.8 mm anterior to the posterior cortical line—in contrast to Wijdicks et al\textsuperscript{26} who reported 8.8 mm—and 0.9 mm distal to the posterior portion of Blumensaat’s line. A significant relationship between limb rotation and the distance of the femoral attachment from the posterior cortical line was observed.

**Isometry**

The isometric behavior of the MPFL has been studied by several investigators. Smirk and Morris\textsuperscript{21} evaluated 4 specimens and considered isometric behavior to be present if there was less than a 5-mm difference in length through the arc of motion from 0° to 120°. They found the most isometric portion of the ligament to be from the native patellar site to a point 1 cm anterior to the native femoral attachment. Steensen et al\textsuperscript{19} studied 11 cadaveric knees, evaluating if there were pairs of points in the native attachments that would be isometric. They measured length change between 3 points (ie, superior, middle, and inferior) of the native femoral origin and 3 similar points on the native patellar attachment. Length between all combinations of femoral and patellar points was measured at 0°, 30°, 60°, 90°, and 120° of flexion. Although some pairs did not show isometry, the combination of
the superior femoral point to the inferior patellar point showed relative isometry (ie, less than 2 mm) between 0° and 90° of flexion. Stephen et al27 reported the femoral attachment point midway between the medial epicondyle and the adductor tubercle in 8 knees. During length testing, they found that changes in position proximally or distally had a larger effect than changes anteriorly or posteriorly. Additionally, the authors27 reported that the femoral attachment was approximately 60% and 50% of the total anteroposterior dimension from the anterior and distal margins of the medial femoral condyle, respectively.

Table

Summary of Studies Reporting the Anatomy of the Medial Patellofemoral Ligament

<table>
<thead>
<tr>
<th>Study</th>
<th>Specimen (No.)</th>
<th>Mean Length, mm ± SD</th>
<th>Width</th>
<th>Mean Thickness, mm ± SD</th>
<th>Femoral Insertion</th>
<th>Patellar Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baldwin20</td>
<td>Cadaveric (50)</td>
<td>59.8±4.8</td>
<td>10.6±2.9 mm (femoral attachment)</td>
<td>-</td>
<td>Bony groove between adductor tubercle and medial epicondyle</td>
<td>Upper two-thirds of patella</td>
</tr>
<tr>
<td>Feller et al16</td>
<td>Cadaveric (20)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Anterior to medial epicondyle</td>
<td>Superomedial border</td>
</tr>
<tr>
<td>Fujino et al10</td>
<td>Cadaveric (31)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10.6±2.5 mm distal to adductor tubercle along the long axis of femur</td>
<td>-</td>
</tr>
<tr>
<td>LaPrade et al18</td>
<td>Cadaveric (8)</td>
<td>65.2</td>
<td>-</td>
<td>-</td>
<td>10.6 mm proximal and 8.8 mm posterior to medial epicondyle</td>
<td>Midpoint of ligament attached 41% of total patellar height</td>
</tr>
<tr>
<td>Nomura et al14</td>
<td>Cadaveric (20)</td>
<td>58.8±4.7</td>
<td>12.0±3.1 mm (midportion)</td>
<td>0.44±0.19</td>
<td>9.5±1.8 mm proximal and 5.0±1.7 mm posterior from center of medial epicondyle</td>
<td>27%±10% of patellar height</td>
</tr>
<tr>
<td>Philippot et al15</td>
<td>Cadaveric (23)</td>
<td>57.7±5.8</td>
<td>12.2±2.6 mm (femoral attachment)</td>
<td>-</td>
<td>10.7±3.3 mm posterior and proximal to medial epicondyle</td>
<td>Upper half of medial edge of patella</td>
</tr>
<tr>
<td>Smirk and Morris21</td>
<td>Cadaveric (25)</td>
<td>58.3 (range, 47.2-70.0)</td>
<td>-</td>
<td>-</td>
<td>Posterior portion of medial epicondyle, 1 cm distal to adductor tubercle</td>
<td>Superomedial patella (88% of knees)</td>
</tr>
<tr>
<td>Steensen et al19</td>
<td>Cadaveric (11)</td>
<td>-</td>
<td>17 mm at patellar insertion</td>
<td>-</td>
<td>Anterior aspect of medial epicondyle</td>
<td>6.1 mm from superior edge of patella to superior edge of MPFL</td>
</tr>
<tr>
<td>Tuxøe et al19</td>
<td>Cadaveric (39)</td>
<td>53 (range, 45-64)</td>
<td>19 mm (femoral attachment)</td>
<td>-</td>
<td>Adductor tubercle proximal to medial collateral ligament and distal to adductor magnus</td>
<td>Proximal two-thirds of medial patella</td>
</tr>
</tbody>
</table>

Abbreviation: MPFL, medial patellofemoral ligament.
Victor et al\textsuperscript{28} found the MPFL attachment site to be in a bony depression proximal and posterior to the medial epicondyle and distal and anterior to the adductor tubercle using computed tomography for 12 cadaveric specimens. The distance between attachment sites decreased with increasing degrees of flexion. A difference in length of 1 mm was noted between 0° and 40°, 2.6 mm between 0° and 90°, and 2.4 mm between 90° and 120° of flexion. The change in tendon length was nearly linear between 40° and 120° of flexion.\textsuperscript{28}

An in vivo study using magnetic resonance imaging to analyze MPFL length changes in 20 patients was performed by Higuchi et al\textsuperscript{12} in 2010. They found slight changes in MPFL length between 0° and 60° and a decreased distance from 60° and higher. The authors, therefore, advocated for graft tensioning at 60° of flexion to replicate the native biomechanics of the MPFL. In a similar in vivo study by Yoo et al,\textsuperscript{29} computed tomography scans of 10 patients revealed length changes between 4 femoral points and 2 patellar points. The most isometric graft spanned from a point midway between the medial epicondyle and the adductor tubercle to a patellar point located 45% of the distance between the superior pole and the equator. In contrast to the study performed by Higuchi et al,\textsuperscript{12} the authors\textsuperscript{29} recommended graft tensioning at 30° of flexion on the basis of their ideal virtual graft placement showing tightening until 30° of flexion with progressive relaxation thereafter.

Tateishi et al\textsuperscript{30} reconstructed the MPFL in 27 patients using a femoral site between the medial epicondyle and the adductor tubercle. The authors used intraoperative isometric testing and plain radiographs to assess the position of their femoral tunnel. Following isometric reconstruction of the MPFL (defined as less than 5 mm of length change), they compared the distance between the femoral and patellar insertion points on a lateral radiograph at terminal extension and 120° of flexion. Their findings implied that 10 grafts elongated with flexion, 8 shortened, and 9 were isometric. A correlation with decreased motion at 4 and 8 weeks was noted in the patients with increased graft length with flexion.\textsuperscript{30}

**Discussion**

Medial patellofemoral ligament reconstruction has emerged as a promising treatment for recurrent patellar dislocation.\textsuperscript{31-33} There remains some uncertainty as to the ideal site for femoral attachment of the reconstructed ligament and how to surgically achieve the desired position. The current authors reviewed the literature on the anatomy of this ligament. There is a trend to place the native attachment site between the medial epicondyle and the adductor tubercle.

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**Figure 1:** Coronal (A) and sagittal (B) 3-dimensional computed tomography reconstruction showing the femoral insertion site of the medial patellofemoral ligament (blue) in relation to the adductor tubercle (red) and medial epicondyle (yellow).

**Figure 2:** Radiographic landmarks for placement of the femoral tunnel during reconstruction of the medial patellofemoral ligament according to Schöttle et al\textsuperscript{22} (A), Redfern et al\textsuperscript{23} (B), and Wijdicks et al\textsuperscript{24} (C). Note the crossing sign, indicating the presence of trochlear dysplasia.
Surgical goals can vary as one can attempt anatomic, isometric, or anisometric graft placement. There may be benefits and drawbacks to each approach. Anatomic reconstruction relies on previous literature reporting cadaveric dissection and/or radiologic guidance to aid graft placement. As highlighted, there is some variability to the findings of these studies and surgeons must choose the method they consider most reliable on the basis of available evidence. Studies reporting radiographic landmarks for femoral tunnel placement have generally been limited by the number of specimens included. These studies often do not report the presence or absence of abnormal anatomic factors often seen in patients with recurrent patellar dislocation. It is possible that these studies report the native location of the MPFL attachment in normal knees, which may not be completely applicable for patients with recurrent instability. Additionally, if an anatomy-altering procedure, such as a tibial tubercle osteotomy or trochleoplasty, is performed, the native anatomy of the femoral attachment may no longer be an appropriate site for graft attachment.

Intraoperative isometry testing may allow one to choose a femoral tunnel position that results in either an isometric or anisometric graft. An isometric femoral site may allow the reconstructed ligament to perform through the entire arc of motion. This may be particularly helpful when patella alta is present, as the native ligament may be elongated (“MPFL longa”) and may become lax before trochlear engagement. Isometric placement may avoid over-tensioning of the graft, as it can be fixed while the patella is engaged in the trochlea and would still be appropriately tensioned when the knee is in extension and the patella is no longer engaged. Isometric graft placement may also be advantageous when performing concomitant procedures such as a tibial tubercle osteotomy or trochleoplasty, as the resultant graft can be positioned to accommodate the altered anatomy.

Anisometric placement may more closely replicate the natural function of the ligament. One must cautiously place the graft to achieve the desired anisometry. It is important to avoid overtensioning the graft, which may result in an increase in patellofemoral contact forces and potential graft failure. In a series of 20 patients (23 knees), Thunaat and Erasmus reported satisfactory results following MPFL reconstruction with an anisometric graft. The authors placed their femoral tunnel using intraoperative isometry testing. At 3 months, 9 of 20 patients possessed an extensor lag, which resolved in all but 1 patient at 24 months. No patients in this series experienced recurrent dislocation. The authors cautioned against overtensioning the graft, especially in the setting of preexisting patella alta. This highlights a potential technical error for MPFL reconstruction using an anisometric graft.

**Conclusion**

To the authors’ knowledge, there are currently no studies comparing outcomes between anatomic, isometric, or anisometric MPFL reconstruction. Patients with recurrent dislocation of the patella have a high prevalence of abnormal anatomic factors, including patella alta, increased Q-angle, rotational deformities, and trochlear dysplasia, which may change the validity of previous cadaveric studies reporting the anatomy of the MPFL insertion site. Isometric and anisometric graft placement both may have their strengths and weaknesses, with no comparative research to support one method over the other. The current authors prefer a reconstruction resulting in an isometric MPFL graft. The rationale for this includes the ability to create a graft of appropriate tension throughout the arc of motion while avoiding the potential technical errors associated with anisometric graft reconstruction and those techniques relying solely on radiographic landmarks. Additionally, patients presenting with recurrent patellar instability are screened for contributing anatomic factors (eg, patella alta, increased femoral anteverision, increased tibial tubercle-trochlear groove distance, and trochlear dysplasia) and may undergo concomitant procedures that alter the native anatomy of the patellofemoral joint. Isometric graft reconstruction allows for a reproducible femoral attachment site regardless of whether the surrounding anatomy is being altered. Although knowledge about patellar dislocation and associated anatomic factors is expanding, there remain areas that are not completely understood. Further research could offer increased insight into treatment of this difficult problem.

**References**


