

Lateral Patellofemoral Ligament

An Anatomic Study

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Background: Medial instability of the patellofemoral joint is a rare but known phenomenon that may result from an incompetent lateral patellofemoral ligament (LPFL). Surgical reconstruction of the LPFL has been described. However, anatomic details of the ligament have not been the subject of scrutiny.

Purpose: To describe the anatomic origin and insertion of the LPFL.

Study Design: Descriptive laboratory study.

Methods: Ten fresh-frozen, unpaired human cadaveric knees (mean age, 57 years) were dissected to identify the LPFL. The dissection was carried out by elevating the iliotibial band to expose the deep capsular layer of the knee joint, followed by a medial parapatellar approach to the knee. Then the quadriceps and patellar tendons were sectioned, and the LPFL was isolated by visualization and palpation. The LPFL was dissected to reveal its origin and insertion; these were measured with respect to the lateral epicondyle and the superior-inferior axis of the lateral patella, respectively.

Results: On average, the LPFL had a variable point of origin in location as well as width about the lateral epicondyle. The LPFL originated, on average, 2.6 mm distal (range, 13.1 mm proximal to 11.4 mm distal) and 10.8 mm anterior (range, 7.3 mm posterior to 14.9 mm anterior) to the lateral epicondyle. The LPFL insertion on the patella was more reliably found to be about 45% (range, 23.7%-58.4%) of its lateral articular surface. The insertion on the patella was found to be in the middle third of the lateral patella.

Conclusion: The LPFL has an origin that is variable but, on average, was found to be distal and anterior to the lateral epicondyle. The patella insertion was more reliably found to be in the middle third of the lateral patella. These anatomic relationships can help the surgeon reconstruct the LPFL in a more anatomic fashion.

Clinical Relevance: Surgeons who are tasked with reconstruction of the LPFL of a patient with idiopathic medial instability or a previous aggressive lateral release of the knee may reference this article to perform an anatomic reconstruction of the LPFL. We hope that having anatomic landmarks for the reconstruction of this ligament permits the surgeon to operate in an efficient manner that allows for the optimal outcome. This is a rare surgical issue, and no studies are available that provide this information. The little information present in the literature does not provide measurements for anatomic reconstruction; rather, it is limited to descriptions of reconstruction techniques that indirectly provide stability on the lateral aspect of the knee.

Keywords: lateral patellofemoral ligament; medial instability; anatomic reconstruction

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Instability of the patellofemoral joint can result from iatrogenic, traumatic, or idiopathic causes.^{3,7,21} Lateral subluxation due to insufficient medial patellofemoral ligament (MPFL) has been extensively studied anatomically and biomechanically.^{5,16} Medial subluxation or dislocation is relatively uncommon. More than 90% of the described cases in the literature have been secondary to iatrogenic causes, namely, a lateral retinacular release or a tibial tubercle osteotomy.^{7,15,20} The remainder of the cases described have followed a traumatic event or are idiopathic in nature.^{8,18}

Many methods to surgically address insufficient lateral patellofemoral ligament (LPFL) have been described. Some authors have suggested imbricating the lateral retinaculum to prevent subluxation,^{9,15} others advocate soft tissue augmentation using the fascia lata,¹ and some describe a variety of reconstruction methods using autograft and allograft.^{3,19,23,24}

However, the LPFL is poorly understood, and its precise anatomic landmarks have not been detailed. The ligament was first described in 1962 by Kaplan,¹⁰ who called it the *lateral epicondylopatellar ligament*. Later, Reider et al¹⁷ studied this structure in 21 cadaveric knees and labeled it the *lateral patellofemoral ligament*. They and others observed that this structure is a palpable thickening of the lateral joint capsule in the deep transverse layer of the lateral retinaculum, connecting the lateral patella to the lateral femoral condyle.^{6,13}

Vieira et al²⁶ sought to define the function of the LPFL in 10 fresh cadaveric knees. The investigators resected the ligament in these cadavers and observed that the patella luxated medially. They concluded that the LPFL played a role in medial instability of the knee. Merican et al¹³ sought to define the stiffness and the strength of the tissues that provide lateral restraint to the patella. Luo et al¹¹ monitored the stresses on the ligament during knee range of motion to find the position of the knee that leads to the highest stress on the LPFL.

To our knowledge, little is known about the morphologic characteristics and objective relationship of the LPFL to known anatomic landmarks in fresh-frozen cadaveric specimens. The purpose of this study was to define the anatomic origin and insertion of the LPFL in relationship to the lateral epicondyle of the femur and the lateral aspect of the patella, respectively. These data will be useful for the surgeon reconstructing the LPFL.

METHODS

Dissection

Ten fresh-frozen, unpaired cadaveric knees were dissected to determine the morphologic characteristics and anatomic landmarks of the LPFL. None of the knees had evidence of previous surgical intervention. All dissections were carried out by 2 authors (K.N.S. and S.F.D.) and all measurements were made by one of the authors (K.N.S.) to allow for uniform data collection. The average age of the cadaveric specimens was 57 years. These cadavers were procured from a company that collects donated human tissues for research.

Dissection Protocol

The specimens used in the study were thawed overnight prior to the dissection. Dissection was begun laterally along the knee through skin and subcutaneous tissue, carrying down dissection to the level of the iliotibial band. The iliotibial band was sharply elevated from its insertion on the Gerdy tubercle and reflected proximally. This exposed what

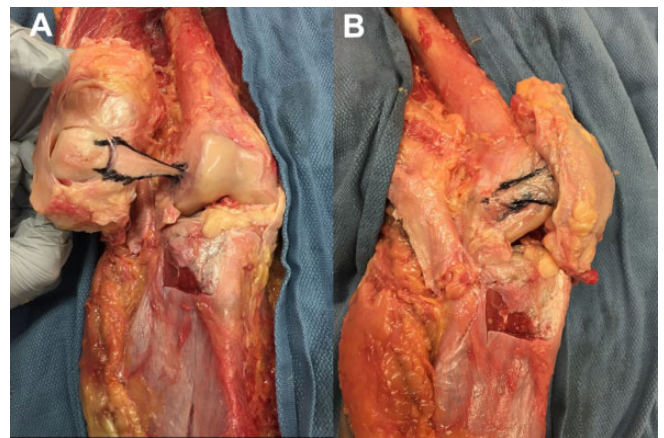


Figure 1. The lateral patellofemoral ligament (LPFL) outlined in a cadaveric specimen. (A) After dissection (as described in the Methods), the patella is reflected laterally, providing an intra-articular view of the LPFL (outlined in black). (B) Lateral image of the knee with the LPFL outlined in black.

Fulkerson and Gossling⁶ defined as the deep transverse retinaculum. Andrikoula et al² also defined the transverse patellofemoral ligament under the superficial retinaculum in the deep transverse retinacular layer. As the authors described, at this level a tendinous thickening was found running from the lateral epicondyle of the femur to the lateral patella, which we identified as the LPFL. The LPFL was also easily palpated at this point from an extra-articular vantage point.

Next, a medial parapatellar approach to the knee was carried out from the other side, and the patellar tendon and quadriceps tendon were sectioned to localize the LPFL both extra- and intra-articularly. The ligament was identified by palpation as a discrete thickening of the lateral capsule, with distinct superior and inferior borders, invested in the transverse layer of the lateral retinaculum. On closer inspection, the thicker fibers of the LPFL were clearly visible in the retinacular layer. Redundant synovium was resected, and the LPFL was isolated (Figure 1).

The LPFL was then dissected from the joint capsule along the palpable thickness as well as its footprint on the femur and patella. Measurements of the ligament itself, its origin, and its insertion in relation to known anatomic landmarks (lateral edge of the patella and tip of the lateral femoral epicondyle) were obtained by use of hand-held, manual calipers (capable of measuring differences of up to 1/100 cm). The patellar insertion of the LPFL was evaluated by first determining the height of the patellar articular cartilage (Figure 2A). The LPFL insertion on the patella was then marked with a marker at the superior and inferior edge of the ligament. The distance from the superior articular surface of the patella to the superior and inferior attachment of the LPFL was then determined (Figure 2, B and C, respectively), allowing for calculation of the width of the patellar attachment of the LPFL (Figure 2, D). Because patellar size varies between patients, we calculated the percentage of the lateral patellar surface to which the LPFL attaches (Figure 2, calculated as D/A).

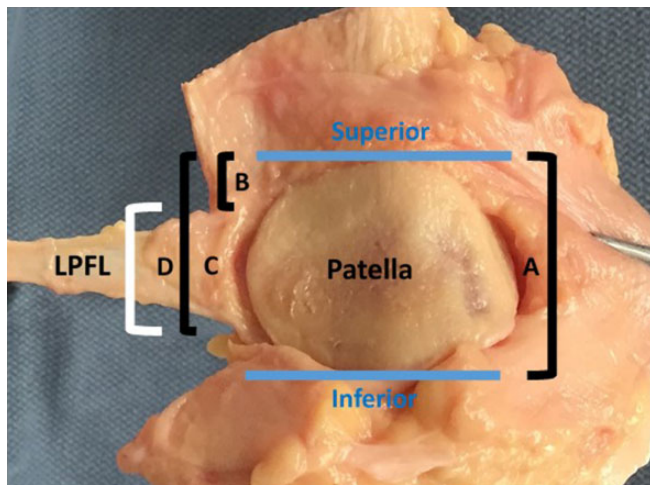


Figure 2. Image representing our method for determining the patellar insertion of the lateral patellofemoral ligament (LPFL). A shows where the total height of the patellar articular surface is measured. B represents the distance from the superior aspect of the articular cartilage to the superior LPFL attachment. C represents the distance from the superior articular surface to the inferior LPFL attachment. The distance D is calculated to determine the width of the LPFL patellar attachment ($D = C - B$).

Next, the anatomic features of the femoral attachment were determined. The parallel and perpendicular axes of the femur were determined (Figure 3A) by use of a Kirschner wire (K-wire) bent to 90°. One arm of the K-wire was aligned with the long axis of the femur and centered on the lateral epicondyle. *Positive* was defined as proximal and anterior on the x and y coordinate axes, respectively. Using these axes centered on the tip of the lateral femoral epicondyle, we determined relative distance in a proximal-distal relationship as well as an anteroposterior relationship for the LPFL origin. The center of the LPFL origin was marked with a marker. An absolute distance between the lateral epicondyle and the center of the LPFL was obtained (Figure 3B). Finally, the insertional width of the femoral attachment of the LPFL was measured and recorded.

Analysis

Data were recorded in Microsoft Excel. In addition to observational measurements, average distances were calculated. The percentage of the articular surface for which the LPFL attaches was also calculated.

RESULTS

The average height of the patellar articular cartilage was 32.2 mm (range, 27.8-35.7 mm; SD, 3 mm). The average width of the patellar attachment of the LPFL was 14.3 mm (range, 8.1-16.8 mm; SD, 2.5 mm). This correlated to the LPFL insertion on the patella to be an average of 45% (range, 23.7%-58.4%) of the lateral width of the

patella. The average width of the femoral attachment of the LPFL was 11.7 mm (range, 9-13.9 mm; SD, 1.9 mm). The proximal-distal attachment of the LPFL relative to the lateral epicondyle varied, with 7 specimens having attachments distal to the epicondyle, and 3 proximal, for an average insertion point of 2.6 mm distal to the epicondyle (range, 13.1 mm proximal to 11.4 mm distal; SD, 7.1 mm) (Figure 4). The anteroposterior attachment also varied, with 9 samples having attachments anterior to the epicondyle and 1 attaching posterior. The average attachment point was 10.8 mm anterior to the epicondyle (range, 7.3 mm posterior to 14.9 mm anterior; SD, 6.5 mm) (Figure 5). Overall, the absolute distance from the epicondyle was 14.5 mm (range, 10.6-20.6 mm; SD, 3.3 mm). The detailed measurements for each sample can be found in Table 1.

DISCUSSION

Medial patellar instability is a recognized problem in patients with anterior knee pain.^{12,18-20,22} Most commonly, this has been reported as an iatrogenic consequence of lateral retinacular release, which inadvertently transects the ligamentous structures, at least of the deep layers.^{7,12} Kaplan¹⁰ first described the anatomic characteristics of the lateral side of the knee and identified a *lateral epicondylopatellar ligament* running at the level of the deep transverse retinaculum. This was confirmed by Fulkerson and Gossling⁶ and was later named the *lateral patellofemoral ligament* by Reider et al.¹⁷ The origin and insertion were not described in detail by Kaplan, but Fulkerson and Gossling briefly described the epicondylopatellar ligament as originating from the lateral intermuscular septum and lateral epicondyle and inserting on the proximal to middle portion of the patella. In our study, we found the origin of the LPFL on average to be distal and anterior to the lateral epicondyle and its insertion to be in the middle third of the patella.

Waligora et al²⁷ described the anatomic features of the extensor mechanism of the knee. In contrast to our study, Waligora et al found the LPFL in only 1 of 18 specimens. However, those investigators used specimens preserved in formalin, which may alter the structure of the ligament and prevent investigators from performing as precise a dissection as allowed by our fresh-frozen specimens. Similarly, Capkin et al⁴ recently reported their results of anatomic dissection of the LPFL on embalmed human cadaveric knees. The authors described the anatomic origin of the ligament on the femur by dividing the lateral condyle in thirds in the vertical and sagittal planes; they found that the LPFL originated from the central section in both the vertical and sagittal planes in a majority of the knees. The authors did not report the anatomic insertion of the LPFL on the patella. Although our study and that by Capkin et al had similar goals, the differences between the studies are notable. Capkin et al used embalmed knees, whereas we used fresh-frozen specimens; some evidence indicates that embalming may affect the properties of tendinous and ligamentous processes.²⁵ The other difference is that instead

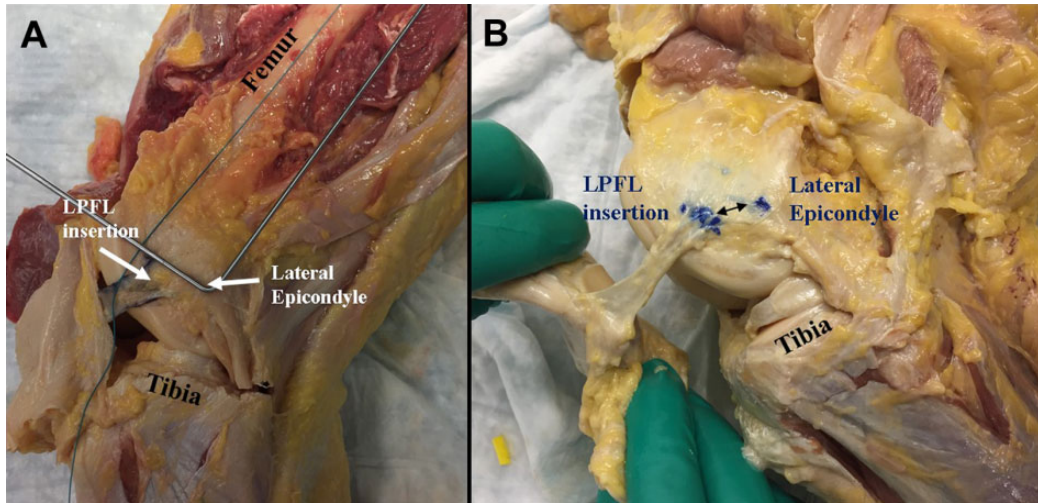


Figure 3. (A) Image showing how we determined the relative distance of the lateral patellofemoral ligament (LPFL) origin from the lateral epicondyle based on the axis of the femur we established (described in Methods). The 90° bent wire is centered on the tip of the lateral epicondyle with the long end of the wire parallel to the long axis of the femur. Distance to the center of the LPFL origin is measured along the short and long ends of the wire. (B) Absolute distance (black double-headed arrow) was calculated from the tip of the lateral epicondyle to the center of the LPFL femoral attachment. In this specimen, the attachment was distal and anterior to the lateral epicondyle.

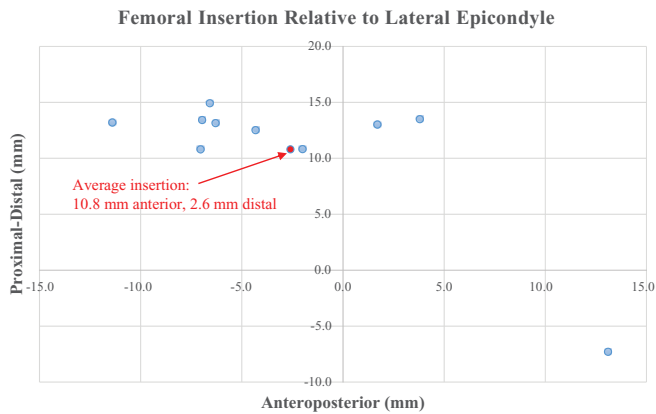


Figure 4. Origin of the lateral patellofemoral ligament on the femur relative to the lateral epicondyle plotted for all specimens. The x-axis represents the anteroposterior direction of the femur, while the y-axis is the proximal-distal distance. The red dot, as labeled, represents the average insertion on the femur.

of reporting the LPFL origin as a factor of zones in 2 different planes on the lateral condyle, we report average distances in millimeters from the lateral epicondyle (coordinate axis and absolute distance), an easily palpable and identifiable structure of the lateral femur. Additionally, we report its insertional details on the patella in quantifiable values with the goal of providing absolute values from anatomic landmarks, which may help the surgeon when tasked with reconstructing the LPFL.

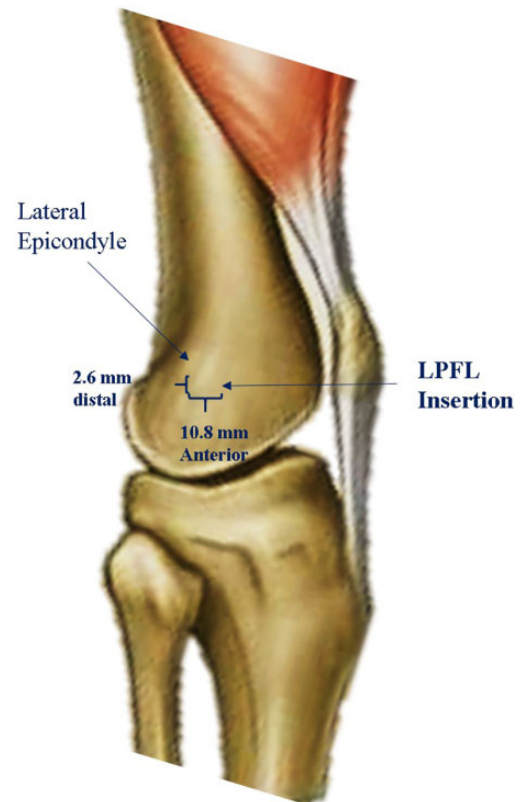


Figure 5. Model of a distal femur depicting the average distance of the lateral patellofemoral ligament (LPFL) from the lateral epicondyle as found in this anatomic study.

TABLE 1
Anatomic Relationships of the Femoral and Patellar Insertion of the
Lateral Patellofemoral Ligament (LPFL) for All 10 Samples^a

Specimen No. and Side	Femoral Insertion			Patellar Insertion					
	Proximal- Distal ^b	Anteroposterior ^c	Absolute Distance of LPFL	Insertion Width (LPFL)	Cartilage Height	Superior Pole to Upper Insertion	Superior Pole to Lower Insertion	Patellar Insertion Width	Percentage of Articular Surface
1 L	13.1	-7.3	10.8	13.6	35.7	7.1	22.6	15.5	43.3%
2 L	1.7	13.0	10.6	12.7	34.1	9.3	17.4	8.1	23.7%
3 R	-2.0	10.8	11.4	12.7	35.0	9.4	25.5	16.0	45.9%
4 R	-6.3	13.1	16.8	13.9	33.7	10.6	25.2	14.6	43.4%
5 R	-4.3	12.5	12.4	9.0	29.6	5.5	19.6	14.2	47.8%
6 L	-7.0	10.8	15.7	10.7	34.1	13.3	26.1	12.8	37.5%
7 L	-6.6	14.9	16.5	9.7	27.9	5.0	20.0	15.0	53.9%
8 R	3.8	13.5	13.3	10.2	29.2	7.3	23.6	16.3	55.9%
9 R	-7.0	13.4	16.6	13.8	28.7	5.0	21.8	16.8	58.4%
10 L	-11.4	13.2	20.6	10.5	34.1	7.1	20.7	13.6	39.8%
Average	-2.6	10.8	14.5	11.7	32.2	8.0	22.3	14.3	45.0%
SD	7.1	6.5	3.3	1.9	3.0	2.7	2.9	2.5	10.2%
Minimum	-11.4	-7.29	10.6	9	27.86	5	17.4	8.07	23.65%
Maximum	13.1	14.92	20.6	13.9	35.68	13.3	26.08	16.78	58.43%

^aAll values given as millimeters, except for percentage of articular surface. L, left; R, right.

^bPositive values indicate proximal.

^cPositive values indicate anterior.

Navarro et al¹⁴ dissected 20 fresh cadaveric knees, identifying the LPFL in each. The mean width of the LPFL in that study (16.05 mm) was slightly wider than our specimens (average width 14.3 mm), but this difference likely is not of practical importance. However, Navarro et al did not describe the location of the femoral or patellar insertion.

The function of the LPFL in patellar positioning has also been studied. In a cadaveric study, Vieira et al²⁶ defined the LPFL as a lateral capsular thickening measuring 13 mm in width, similar to the average of 14.3 mm found in our study. After sectioning the ligament, Vieira et al found that the patella displaced medially, demonstrating the structure's importance in protecting the patella against medial instability. Given this finding, one may argue that patients undergoing a lateral release, which essentially sections a portion of the lateral capsule and the LPFL, would experience medial instability. However, most patients do not report this complication. It is possible that patients who are asymptomatic may have started with a significantly abnormal LPFL and lateral tissues, which would allow for better patellar tracking after the release. Additionally, contributions from the iliotibial band, the patellar retinaculum, and the joint capsule continue to provide some restraint against medial instability after a lateral release.

Several authors have described techniques of LPFL reconstruction to treat medial patellar instability.^{3,19,23,24} Saper and Shneider¹⁹ recommended dissecting a central slip of the quadriceps tendon and routing it under the lateral retinaculum to reconstruct the LPFL. The rerouted quadriceps slip is then secured to the lateral epicondyle with a suture anchor. However, based on the results of the

current study, if the anchor is placed at the lateral epicondyle, the origin of the reconstructed LPFL may be too posterior and proximal. Teitge and Torga Spak²³ described their method of using a partial-thickness quadriceps tendon graft for reconstruction. A bone block from the patella is removed with the quadriceps tendon, partial-thickness autograft. An isometric device is then used to find the isometric point on the lateral femoral condyle, where a recessed socket is created. The patellar bone block is fixed there with 4.0-mm lag screw. The quadriceps graft is then tunneled through the middle third of the patella, from the lateral edge to the middle of the patella, where the graft exits anteriorly. The graft is then sutured over the quadriceps expansion medial to the medial edge of the patella. While the graft attaches to the middle third of the lateral patella, the femoral attachment is placed at the isometric point of lateral femoral condyle, which may or may not represent the anatomic origin of the LPFL as defined in this study. Borbas et al³ described their method using a gracilis autograft for reconstruction. Their technique involves tunneling the graft from the distal to proximal third of the lateral patella and fixing to the femur 5 mm proximal and posterior to the lateral femoral epicondyle. Based on the results of the current study, these techniques would not result in anatomic graft placement.

In one of our cadaveric specimens, the femoral origin of the LPFL was significantly different than the rest. The insertion in that specimen was found to be proximal and posterior to the lateral femoral epicondyle, while most were distal and anterior to the epicondyle. The outlier specimen may have come from an individual who had an anatomic variation of the LPFL or a pathologic condition related to the LPFL.

Our study has a few potential limitations. We measured absolute distances from the lateral epicondyle and did not attempt to reference our measurements to the size of other anatomic structures. It is likely that the distance from the lateral epicondyle may change with differently sized specimens. Also, our small sample size of 10 cadaveric knees may introduce some variability in the measurement data; a larger sample size may reduce the standard deviations reported. Finally, we defined the center of the LPFL attachment at the femur and patella, but the anatomic center of the ligament does not necessarily represent an isometric point or the functional center of the ligament. Further biomechanical studies will be needed to elucidate the functional center of this ligament.

CONCLUSION

This study defines the anatomic origin and insertion of the LPFL in relation to known bony landmarks. On average, the LPFL was found to be centered 2.6 mm distal and 10.8 mm anterior to the lateral femoral epicondyle. The insertion on the lateral patella was found to be broad, measuring 14.3 mm, or roughly 45% of the articular surface, and centered on the middle third of the patella. It is our hope that this information will be useful for surgeons performing an anatomically accurate reconstruction of the lateral patellofemoral ligament.

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