Technical Note

Physeal-Sparing Medial Patellofemoral Ligament Reconstruction With Suture Anchor for Femoral Graft Fixation

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Abstract: Patellar instability is a common problem in the active pediatric population. When nonoperative treatment of the instability fails, growth-respecting surgical stabilization techniques are required. As the incidence of medial patellofemoral ligament (MPFL) reconstruction has increased, techniques have improved to avoid physeal injury to the distal femur. These techniques are technically demanding because of the small size of the distal femoral epiphysis in children, as well as the relatively large socket size (7-8 mm in diameter, >20 mm in length) required for sound fixation with a tenodesis screw as originally described. The size of the femoral tunnel for interference fixation puts the surrounding structures at risk of damage. We present a modification of the epiphyseal socket technique for anatomic growth-sparing MPFL reconstruction using a small soft anchor for femoral graft fixation. This has the proposed advantages of diminishing volumetric bony removal from the epiphysis; increasing the margin of safety with respect to notch, trochlear, and/or physeal damage; and reducing the risk of thermal damage to the physis during socket reaming. This technique is technically simple and can be easily learned by surgeons familiar with adult MPFL reconstruction techniques.

Patellar instability is a common problem in the active pediatric population. When nonoperative treatment of the instability fails, growth-respecting surgical stabilization techniques are required. Given the contraindication for tibial tubercle osteotomy and trochleoplasty in skeletally immature patients, medial-based soft-tissue stabilization procedures are the workhorses in this pediatric population. A multitude of techniques have been described, including both nonanatomic and anatomic reconstructions.[1] Pediatric cadaveric studies have elegantly shown that in most children, the medial patellofemoral ligament (MPFL) origin on the femur is a few millimeters distal to the distal femoral physis, in the usual location between the medial epicondyle and the adductor tubercle. Techniques using the adductor magnus tendon as a "sling" for femoral fixation are cost-effective and minimize risk to the distal femoral physis; however, this comes at the cost of a nonanatomic attachment site of the reconstruction on the femur (too proximal), potentially resulting in a non-isometric graft, loss of knee motion, and elongation of the graft as growth occurs. Suturing a graft to the femoral periosteum at the anatomic MPFL origin has also been described, but the fixation biomechanics are unproven, especially in older children whose periosteum is not as stout.

These considerations led to the development of a physeal-sparing MPFL reconstruction technique using an epiphyseal socket in the femur, somewhat analogous to the sockets used in all-epiphyseal anterior cruciate ligament reconstruction.[2] This technique has enjoyed good clinical outcomes; however, it is quite technically demanding because of the small size of the distal femoral epiphysis in children, as well as the relatively large socket size (7-8 mm in diameter, >20 mm in length) required for sound fixation with a tenodesis screw as originally described. In fact, a recent magnetic resonance imaging–based anatomic study has shown that an 8 × 20–mm medial epiphyseal socket in the distal femur will violate the physis, intercondylar notch, or trochlea 41% of the time.[3] This risk can be lowered with a perfect trajectory aiming 20° distal and

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20° anterior; however, the margin for error in this trajectory is extremely small, and in the experience of the senior author (J.C.R.), smaller children undergoing this procedure might not be able to accommodate an adequate socket safely.

Our technique consists of a physeal-sparing, anatomic MPFL reconstruction using a soft suture anchor for femoral fixation, with the goal of decreasing the "footprint" of femoral fixation and increasing the margin of safety. Indications and contraindications are listed in Table 1. Soft suture anchors are also used for patellar fixation given their small size and proven biomechanical and clinical track record for this application.

Surgical Technique

Patient Positioning

The patient is positioned supine with all bony prominences padded (Video 1). A nonsterile tourniquet is applied to the proximal aspect of the operative thigh. A removable lateral post (Arthrex Swivel Post) is applied such that it can apply restraint to valgus loading during diagnostic arthroscopy, meeting the lateral thigh approximately at the level of the tourniquet. After diagnostic arthroscopy, a radiolucent triangle or a large stack of towels will be used to maintain the knee in 45° to 60° of flexion during most of the procedure. A C-Armor lateral fluoroscopy drape (TIDI) is applied to the side of the surgical bed ipsilateral to the affected limb. A large C-arm should be positioned on the side opposite the surgical leg and covered with sterile drapes.

Examination Under Anesthesia

The examination under anesthesia serves several important purposes. First, lateral tilt should be assessed. Specifically, one should assess whether any present lateral tilt can be reduced to neutral with manual overpressure. An inability to normalize the patellar tilt is an indication to perform concomitant lateral retinacular lengthening, which can be achieved through a single midline incision that allows access to both the medial and lateral aspects of the patella. In addition, the patient's patellar tracking and stability should be carefully assessed. If the patient has a severe J-sign or obvious patellar "hopping" over a large supratrochlear bump (often seen in the setting of severe trochlear dysplasia), an isolated MPFL reconstruction is unlikely to provide sufficient stability to the patella. Finally, careful analysis and documentation of the patient's native range of motion (including hyperextension, extension, and flexion measurements) are critical to make sure this native arc of motion is maintained after the reconstruction.

Diagnostic Arthroscopy

A standard anterolateral portal is used for diagnostic arthroscopy. No additional portals are needed if no intra-articular abnormalities are seen. The primary goal is to identify any patellofemoral chondral defects requiring treatment. In addition, the degree of patellar tilt, as well as trochlear morphology, is assessed to help decide whether any concomitant procedures (lateral lengthening, trochleoplasty, and so on) are indicated. All fluid should be evacuated from the knee at the end of the arthroscopy to facilitate subsequent dissection.

Patellar Dissection

A 2- to 3-cm incision is made over the medial aspect of the patella, from just distal to the equator to the proximal pole. Dissection should be carried to layer 1 of the medial knee, with attention paid to create full-thickness medial and lateral flaps for eventual closure. At this point, a No. 15 blade can be used to dissect layers 1 and 2 off the medial patella, followed by blunt dissection to expose the interval between layers 2 and 3. Blunt dissection is then carried down to the level of the medial epicondyle. Passage of a Kelly clamp between layers 2 and 3 should be very easy. Significant resistance should clue the surgeon that the instrument is in the incorrect plane, most often between layers 1 and 2.

Patellar Anchor Placement

Electrocautery is used to remove the soft tissue from the medial aspect of the patella from the proximal pole

Table 1. Indications, Contraindications, Risks, and Limitations

Indications*
Recurrent patellar dislocation in skeletally immature patient
TT-TG distance <20 mm
Contraindications
Patient with obligate patellar dislocation
Presence of severe trochlear dysplasia, large supratrochlear bump, or J-sign on clinical examination
TT-TG distance >20 mm
Risks and limitations
In very young patients, double-anchor placement in the patella can theoretically increase the risk of fracture.
Malpositioning or over-tightening of the graft can lead to medial patellar overload.
Off-axis drilling for the medial femoral anchor can cause damage to the medial physis.
Physeal arrest can cause varus alignment of the knee.

TT-TG, tibial tubercle—trochlear groove.

*Simultaneous treatment of a full-thickness cartilage defect is not a contraindication to this technique.

of the equator. The medial edge of the patella is then debrided with a rongeur to create a bleeding trough of bone to accommodate the graft. Fluoroscopy is used to confirm the position of the 2 anticipated anchors on the medial patella. It is particularly important in small pediatric patients to ensure, on a perfect lateral radiograph of the patella, that the anticipated trajectory for anchors is centered from anterior to posterior because the margin of safety is relatively small to avoid joint penetration or anterior cortical breach. The first anchor is placed at the equator, equidistant between the anterior and posterior cortex of the patella, confirmed with fluoroscopy. The second anchor is placed halfway between the equator and the superior pole in the native footprint of the MPFL. Residual MPFL tissue helps to localize this point, and this is again confirmed with a lateral fluoroscopic view. It is our preference to use Smith & Nephew Q-Fix Mini 1.8-mm anchors because these have a high thread pitch compared with core diameter, have a very short drill depth (18 mm), and have a rigid inserter that facilitates insertion into the hard patellar bone.

Medial Femoral Dissection

The medial epicondylar incision is localized with fluoroscopy directly overlying the Schöttle point. The incision is typically 2 cm in length. Appropriate fluoroscopic localization makes it possible to use a smaller incision and avoid having skin flaps dictate the trajectory of drilling for femoral fixation. Sharp dissection is carried down to the fascia. The fascia is then sharply incised directly over the Kelly clamp previously placed between layers 2 and 3.

Femoral Anchor Placement

The most unique portion of this technique is the use of a small soft anchor for femoral fixation. We prefer a Smith & Nephew 2.8-mm double-loaded Q-Fix anchor. The appropriate drill guide is placed at the Schöttle point on a perfect lateral radiograph, and this position is confirmed by direct palpation between the medial epicondyle and the adductor tubercle (Fig 1). Owing to undulation of the distal femoral physis, it often appears as though the anticipated starting point is directly overlying the physis. Therefore, on an anteroposterior view, the drill guide should be confirmed to be distal to the physis and aimed anterior and distal 20° to avoid the notch, trochlea, and physis (Fig 2). Once satisfied with the position, the surgeon can gently impact the guide 1 to 2 mm into bone to prevent slippage. The anchor pilot hole is then drilled, and the anchor is inserted in standard fashion.

Allograft Femoral Fixation

An advantage of this technique is that no back-table graft preparation is required. In addition, because no socket is drilled in the femur, a larger allograft can be used for reconstruction. We prefer a semitendinosus allograft, usually with a folded diameter around 7 mm. The mid portion of the graft is marked with a sterile pen (Fig 3). Allis clamps are placed at either end, and an assistant can hold the graft taut so that its mid portion directly overlies the femoral anchor. Simple cerclage fixation with each set of sutures from the Q-Fix anchor is then achieved, with one suture set on either side of the mark on the graft. Excess suture is trimmed, and adequate fixation strength is confirmed. A Kelly clamp can then be used to shuttle both limbs of the graft into the patellar incision, taking care not to cross the limbs (Fig 4). These are again secured with Allis clamps at their free ends.

Allograft Patellar Fixation

Patellar fixation is performed with the knee in 45° to 60° of flexion with the patella in its native position within the trochlea. One advantage of femoral-first fixation is that there is little to no risk of overtensioning the graft. An assistant should hold the 2 graft limbs vertically so that slack is removed but without any true tension applied. The graft limbs are then marked in the exact location where they overly their respective anchors. This will serve as the landmark for stitching of the graft to ensure appropriate tension. For each anchor, 1 suture limb is passed in a running locking Krackow fashion starting at the mark, working 15 to 20 mm distal, then coming back up to the level of

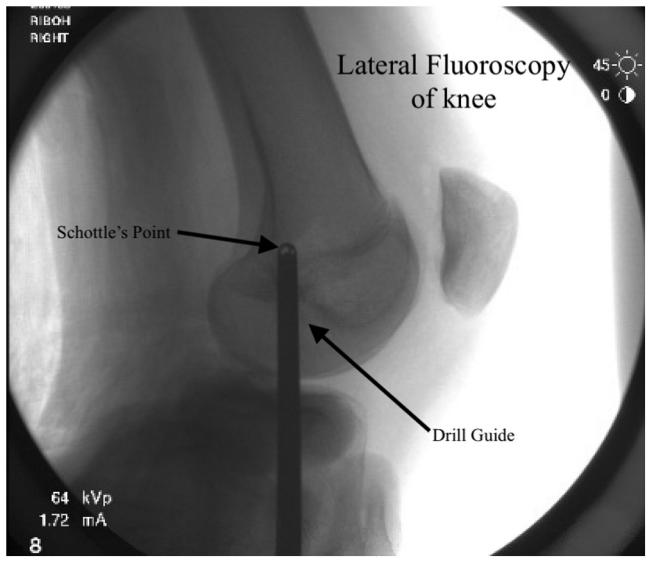

Fig 1. A perfect lateral radiograph of the knee is used to identify the appropriate fixation location of the femoral anchor. The appropriate starting position is between the adductor tubercle and medial epicondyle. Owing to undulation of the distal femoral physis, the starting position often appears to be directly over the physis. Therefore, after guide placement on the lateral radiograph, an anteroposterior radiograph should be used to confirm the location.

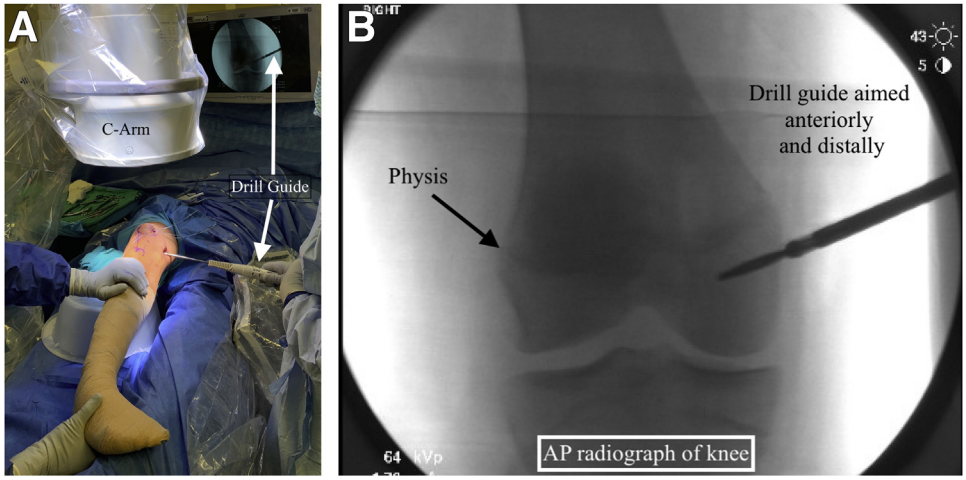

Fig 2. Patient supine, right knee visualized with medial incision. (A) To confirm guide placement, an anteroposterior radiograph should be used. The leg should be held in the same position as it was for the perfect lateral radiograph, and the C-arm should be rotated 90°. The knee should be placed on a bump. (B) On an anteroposterior (AP) radiograph, the guide should contact the bone distal to the physis, aimed anterior and distal 20° to avoid the notch, trochlea, and physis. Once properly placed, the guide may be gently impacted 1 to 2 mm with a hammer. The drill should be inserted partway, and the appropriate position should be confirmed again on radiographs.

the mark. The second limb is passed as a single pass at the level of the mark and will be used as a post to reduce the graft limb to the anchor (Fig 5). One simply pulls tension on the post and ties the 2 suture limbs together. Excess suture is trimmed. Excess graft length is sharply excised, although one should leave 10 to 15 mm of graft proximal to the knot to avoid the sutures cutting out of the free end of the graft (Fig 6). This extra collagen can be incorporated into the retinacular closure. Finally, layers 1 and 2 are closed using No. 0 Vicryl (Ethicon) in a pants-over-vest fashion, providing a medial reefing to augment the reconstruction.

Repeated Examination Under Anesthesia

Examination under anesthesia should be used to ensure full symmetrical range of motion without any tension on the graft. Patellar tracking should be central, with a firm endpoint to lateral translation but preservation of 2 quadrants of medial and lateral translation.

Closure

All the incisions are closed in layers, using No. 2-0 Monocryl (Ethicon) for the deep dermis and running subcuticular No. 4-0 Monocryl for the skin after copious wound irrigation. The arthroscopic portals are closed with No. 3-0 Prolene (Ethicon).

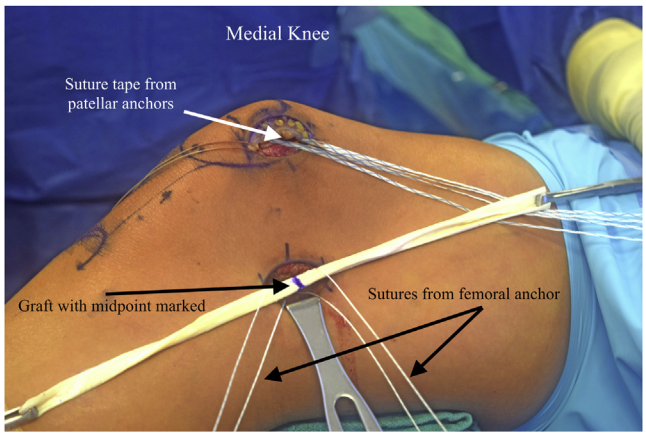

Fig 3. Right knee with medial incision visualized. A semitendinosus allograft with a rolled diameter of 7 mm is used for reconstruction of the medial patellofemoral ligament. The allograft is marked at its midpoint. The graft is laid down over the top of the femoral anchor with sutures separated in pairs. One end of each pair is positioned above the graft, and the other is positioned below the graft. These sutures are then tied over the graft at its midpoint.

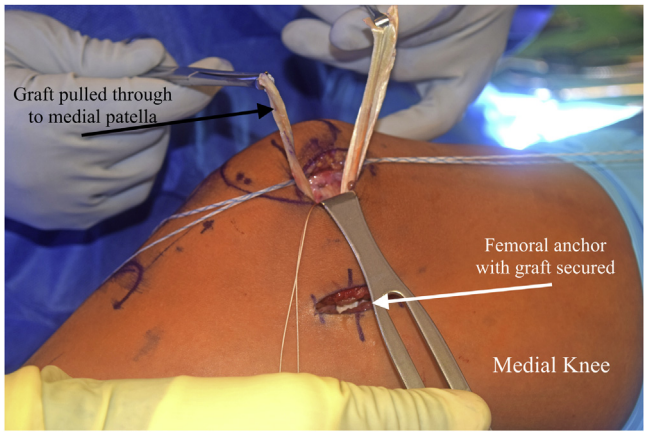

Fig 4. Right knee with medial incision visualized. After femoral fixation, the graft is passed from its fixation on the femoral anchor to the patella between layers 2 and 3 of the medial knee. This passage should be relatively easy, with little resistance. The graft is then pulled with enough tension to ensure it is to full length. The ends are separated so that one end is at each end of the patellar incision.

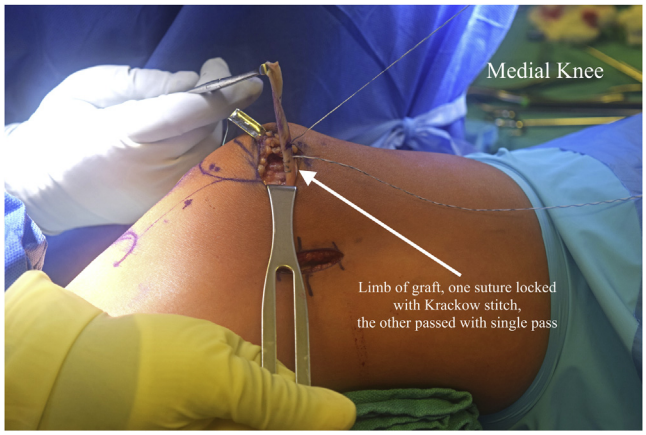

Fig 5. Right knee with medial incision visualized. After graft passage, patellar fixation is performed. We use 2 Smith & Nephew Q-Fix Mini 1.8-mm anchors. The graft is pulled so that there is no redundancy in the graft and is laid over the patella in its natural position. The point on the graft that overlies the anchor should be marked with a marking pen. For each anchor, 1 suture limb is passed in a running locking Krackow fashion starting at the mark on the graft, working 15 to 20 mm distal (toward the femoral anchor), then coming back up to the level of the mark. The second limb is passed as a single pass at the level of the mark and will be used as a post to reduce the graft limb to the anchor.

Fig 6. The graft is pulled into place using the suture post to pull it to the anchor. It is important to avoid over-tensioning the graft. To do this, one should ensure that the knee is in 30° to 45° of flexion and that the patella is in its anatomic position within the trochlear groove. After fixation, there is 10 to 15 mm of extra tissue on each end of the graft to be incorporated into the retinacular closure.

Discussion

In this study, we present a modification of the epiphyseal socket technique for anatomic growth-sparing MPFL reconstruction using a small soft anchor for femoral graft fixation. This has the proposed advantages of diminishing volumetric bony removal from the epiphysis; increasing the margin of safety with respect to notch, trochlear, and/or physeal damage; and reducing the risk of thermal damage to the physis during socket reaming. This technique is technically simple and can be easily learned by surgeons familiar with adult MPFL reconstruction techniques. Pearls for this technique are outlined in Table 2, and key steps are shown in Table 3.

When surgical reconstruction is required for the treatment of recurrent patellofemoral instability, MPFL reconstruction is preferred by 80% of patellofemoral experts.[3] Much work has been performed comparing interference fixation and anchor-based fixation on the patellar side, with the evidence showing identical patient outcomes but higher complication rates using patellar sockets and interference fixation.[4] However, there is only a single report on the use of suture anchor fixation on the femoral side, with good preliminary results.[5] When combined with the reduced risk of physeal or articular damage with suture anchors, we believe suture anchors are a viable and in fact desirable choice for femoral MPFL fixation in children.

One potential question raised with this technique is whether an "onlay" of the MPFL graft will allow for sufficient long-term healing and strength. This has been studied in animal models in the setting of biceps tenodesis, and equivalent healing has been shown with graft onlay versus fixation in bony tunnels.[6] Indeed, most healing occurs outside the tunnel at the cortical surface. In children in particular, given their robust periosteum, a vigorous healing response would be expected. As such, the suture anchor theoretically functions as "temporary" fixation until biological healing occurs at the cortex and periosteum. Another question is whether simple cerclage stitch patterns are sufficient for time-zero biomechanics. In a biomechanical study using anchors on the patella for the MPFL, very high pullout strength was found using a circumferential stitch pattern.[7] In our experience with more than 20 of these reconstructions, no clinical failures have been observed. In conclusion, we propose that physeal-sparing MPFL reconstruction using soft anchors for patellar and femoral fixation offers a simple and safe technique with reproducible anatomic graft placement and favorable clinical outcomes.

Table 2. Pearls and Pitfalls

Technique	Pearls	Pitfalls
Patient positioning	An upside-down basin and stack of towels can be used. A swivel lateral post can be used and then moved once arthroscopy is completed.	
Examination under anesthesia	The surgeon should evaluate for the presence of a severe J-sign and make sure the patient does not have obligate dislocation, which would suggest the patient has a large supratrochlear bump.	
Patellar dissection	To ensure the surgeon is in the correct plane, he or she should be able to pass a blunt instrument toward the medial epicondyle. Resistance could indicate the instrument is in the wrong plane.	If the surgeon accidentally violates the joint capsule, he or she may repair it directly with No. 0 Vicryl, or if there is no cuff (cut off patella directly), the sutures used for the patellar anchors can be used. Before they are passed through the graft, they can be passed through the capsule; this will close the capsular defect.
Patellar anchor placement	A hemostat or drill guide can be used to confirm proximal-distal and anterior-posterior placement. Owing to the curvature of the patella, the proximal anchor should be aimed distally to prevent malposition.	Anterior cortical violation or joint violation can occur, especially in younger patients.
Femoral anchor placement	The surgeon should know the drill depth of whatever system he or she is using. If the surgeon is drilling and feels a hard cortex, he or she should reassess under fluoroscopy because it is likely the notch or trochlea has been encountered. In small patients, a smaller anchor with a shorter depth of drilling should be considered.	If the appropriate position is not reached under the deep fascia medially at the time of anchor drilling, this either can cause the surgeon to shift his or her hand prior to drilling the anchor or will allow soft tissue to cover the hole, making anchor insertion difficult.
Allograft femoral fixation	The surgeon should ensure the graft does not roll when it is secured to the femoral anchor.	
Patellar fixation	The knee should be placed in the degree of flexion at which the surgeon wants to fix the graft (typically 45°-50° on a bump), and no pressure should be applied on the patella. This prevents over-tensioning of the patella.	An assistant should lay down the graft without any tension. Application of tension either through the graft or through the patella can allow for incorrect biomechanics.
Repeated examination under anesthesia	The patient's thigh is held and the knee is allowed to freely flex. The surgeon should evaluate the knee and document its ability to achieve full flexion without over-pressure. Patellar tracking should be re-evaluated with arthroscopy after fixation.	

Table 3. Key Steps

A Radiolucent Bump is Used.
A sterile C-Armor drape is applied to allow lateral radiographs to be obtained.
The patient is confirmed to be an appropriate candidate for MPFL reconstruction.
The surgeon looks for chondral damage that would need to be addressed at the time of surgery.
When dissecting proximally, the surgeon must not violate the VMO as it attaches to the patella.
The surgeon uses fluoroscopy to directly visualize anchor placement on AP and lateral views.
The surgeon's assistant should have very strong control of the patella as the surgeon inserts the anchor and taps it with a mallet.
For medial femoral dissection, the surgeon positions a Kelly clamp between layers 2 and 3, comes down to the medial femoral condyle, and then dissects down sharply through the skin until he or she encounters the Kelly clamp.
No soft tissue should be overlying the femoral anchor when the guide is used to drill the anchor holes.
The allograft is marked at the exact mid portion with a marking pen. The surgeon's assistant will hold the graft taut with the middle of the graft touching the femoral anchor.
Patellar fixation is performed after femoral fixation. The graft is secured with no tension and no translation of the patella.
Pants-over-vest imbrication of the medial capsule can be performed.

AP, anteroposterior; MPFL, medial patellofemoral ligament; VMO, vastus medialis obliquus.

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