

Chronic Quadriceps Tendon Ruptures: Primary Repair of Quadriceps Via Bioaugmentation and Patellar Tendon Lengthening



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Abstract: Quadriceps tendon ruptures are devastating injuries that impair the extensor mechanism of the knee. Complete tears require prompt surgical intervention in order to ensure optimal clinical outcomes. Chronic, neglected ruptures—marked by severe extensor lag, muscular atrophy, and tendon retraction—are difficult to treat. Further, severe patella baja complicates surgical planning. While there is no consensus on optimal treatment for these injuries, many different techniques have been proposed. Unlike many of these approaches, our technique focuses on restoration of patellar height via patellar tendon lengthening. Once patellar height is restored, quadriceps tendon repair can be performed using the native quadriceps tendon. Both the patellar tendon lengthening and the quadriceps tendon repair are augmented with bioinductive implants to ensure optimal healing environments, enabling us to reestablish native extensor mechanism function.

Quadriceps tendon ruptures account for only 1.3% of soft-tissue injuries and approximately one-quarter of injuries to the knee extensor mechanism.^{1,2} Injuries to the extensor mechanism—including quadriceps tendon ruptures, patellar fractures, and patellar tendon ruptures—devastate knee function and limit mobility.^{1,3} Marked by significant extensor lag and appreciable suprapatellar defect, quadriceps tendon ruptures must be promptly diagnosed and treated.^{4,5} Partial tears can be managed conservatively, including casting with the knee in extension for at least 6 weeks.^{6,7} Complete tears require surgical intervention, ideally within 2 weeks of injury.⁴ Beyond the acute and subacute (3-6 weeks) periods, ruptures are

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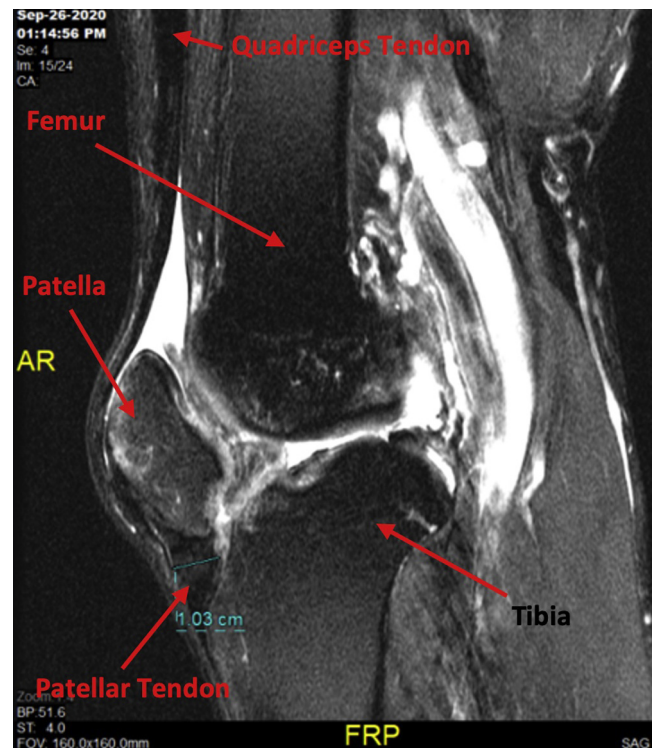


Fig 1. Preoperative magnetic resonance imaging (sagittal view) shows a pathologically thickened patellar tendon in the setting of patella baja secondary to a chronic quadriceps tendon rupture. This patellar tendon measures 1.03 cm in thickness, whereas a normal patellar tendon typically measures about 0.5 cm.

Table 1. Surgical Steps and Tips, Pearls, and Pitfalls of Technique

Surgical Step	Tips	Pearls and Pitfalls
Preoperative radiographic imaging	<ul style="list-style-type: none"> • The Insall–Salvati ratio of the contralateral knee serves as a baseline to restore the patellar height of the operative knee. 	<ul style="list-style-type: none"> • The ratio is measured with the knee in 30° of flexion.
Patellar tendon lengthening	<ul style="list-style-type: none"> • This is appropriate in the setting of thickened and shortened patellar tendon. • Ideally, maintain 50% apposition of the limbs. 	<ul style="list-style-type: none"> • In the setting of less than 50% apposition, consider augmentation with allograft.
Quadriceps tendon repair/reconstruction	<ul style="list-style-type: none"> • Use high-strength polyethylene sutures or suture anchors with locking suture configuration to prevent pull-out. • May need to perform V-Y quadricepsplasty if quadriceps does not reach superior pole of patella after restoration of patellar height. 	<ul style="list-style-type: none"> • Release adhesions proximally with the use of a blunt elevator.
Placement of bioinductive patches	<ul style="list-style-type: none"> • May be easier to deploy implant after moistening or soaking in saline. 	<ul style="list-style-type: none"> • Ensure appropriate use of soft tissue staples vs bone staples.
Augmentation of patellar tendon lengthening with semitendinosus allograft (if necessary)	<ul style="list-style-type: none"> • Put the knee through gentle range of motion, and if the patellar tendon lengthening is under significant tension, then consider augmentation. 	<ul style="list-style-type: none"> • Can perform autograft or allograft augmentation through a small diameter, transverse patellar tunnel.

considered chronic. Depending on the chronicity, treatment can be challenging. These chronic injuries often present with severe muscular atrophy and tendon retraction.^{4,6} Loss of the proximal quadriceps tensioning will not only increase the distance between the end of the ruptured quadriceps and the patella but also will disrupt patellar height, resulting in patellar baja. Given the rarity and complexity of chronic quadriceps ruptures, there is no consensus on treatment. We present our surgical technique focusing on restoration of patellar height via patellar tendon lengthening, quadriceps tendon repair, and augmentation with a REGENETEN (Smith & Nephew, Andover, MA) bioinductive implant.

Surgical Background

Unlike other quadriceps tendon–reconstruction methods, our technique leverages the anatomical and biological advantages of the native knee. To achieve optimal quadriceps function, patellar height must first be approximated. Anatomical placement of the patella reestablishes the lever arm functionality of the extensor mechanism, therefore preventing excessive tension on the newly reconstructed quadriceps tendon and minimizing extensor lag.⁸ This restoration, guided by the height of the contralateral knee, is performed via lengthening of a pathologically thickened patellar tendon.⁹ This procedure is not commonly performed due to concern for disruption of patellar tendon integrity and vascularity.⁹ To mitigate these concerns, bioinductive implants are placed at both the bone–tendon junction of the quadriceps repair and at the lengthening site on the patellar tendon. Augmentation with bioinductive implants has proven to aid in tendon healing in massive rotator cuff tears.^{10,11} These collagen

implants have low complication rates, and new, robust tissue may prevent further tearing and degenerative changes.¹¹ Recent studies also have revealed the efficacy of these implants in other tendinous repairs, including the patellar and gluteal tendons.^{12,13}

Once patellar height is restored, various methods of quadriceps reattachment can be used: primary repair, V-Y quadricepsplasty, and reconstruction with allograft.

Surgical Technique (With Video Illustration)

Patient Evaluation, Imaging, and Indications

Quadriceps ruptures can be assessed both clinically and via magnetic resonance imaging (Fig 1). Acute

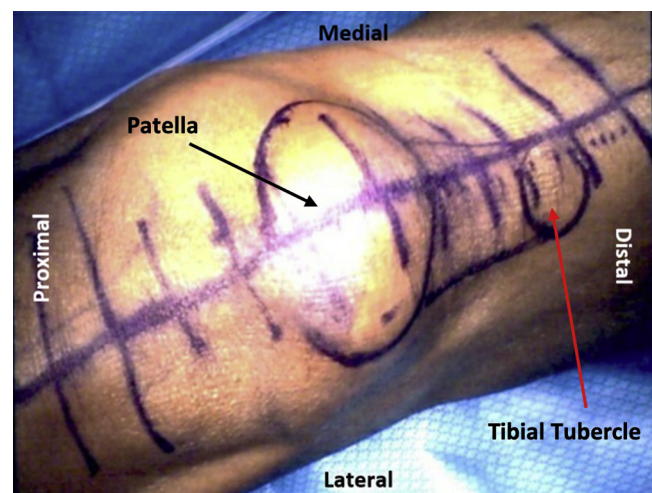
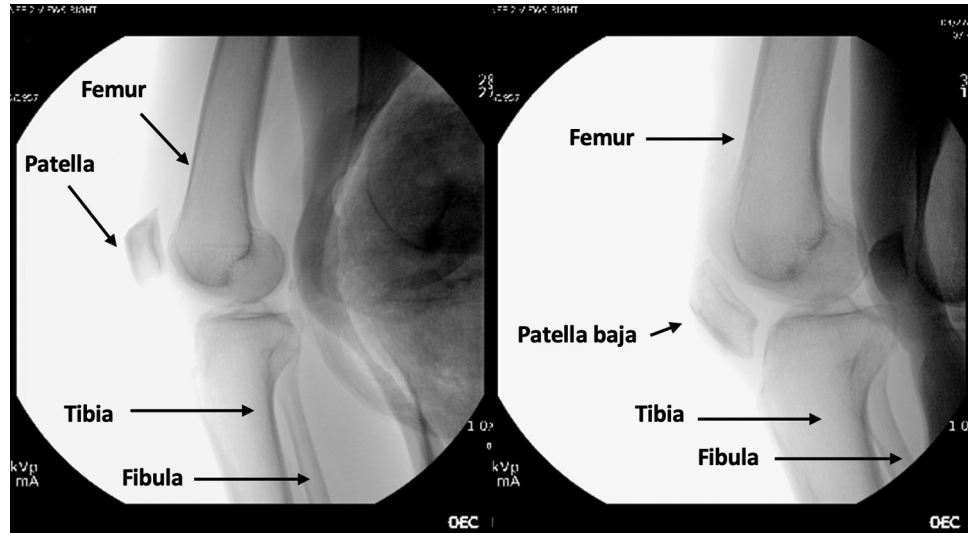


Fig 2. A midline longitudinal incision is used, extending from the distal palpable aspect of the quadriceps tendon to the level of the tibial tubercle. Surgical markings indicating the location of the patella (large circle proximally) and tibial tubercle (smaller circle distally).

Fig 3. Fluoroscopy (lateral view) was performed on both nonoperative (left) and operative (right) knees to assess patellar height prior to draping. Measurements from the inferior pole of the patella to the tibial tubercle (i.e., patellar tendon length) were taken on nonoperative knee in order to determine desired patellar height and patellar tendon length.



ruptures result in severe extensor lag and impaired active extension. Chronic ruptures exhibit similar clinical presentation but also include appreciable atrophy and a palpable gap above the patella. These chronic ruptures can be addressed using our surgical approach with a focus on restoration of patellar height; the technique is discussed in [Video 1](#), and surgical steps, pearls, and pitfalls are presented in [Table 1](#).

Preoperative Analgesia and Patient Positioning

This surgery is performed with the patient in the supine position. General anesthesia with paralysis is administered with either an adductor or femoral nerve block. A tourniquet is applied to the operative leg but not used unless needed; surgical markings are made with a generous longitudinal incision from the area of

the retracted tendon proximally to the level of the tibial tubercle ([Fig 2](#)). An examination under anesthesia may be performed.

Radiographic Imaging

Before draping, fluoroscopy is used to obtain anteroposterior and lateral imaging of both knees. Imaging allows for the measurement of patellar tendon length and height in both operative and nonoperative knees ([Fig 3](#)).

Surgical Approach

A tourniquet is raised and a longitudinal incision is made. Electrocautery is used to reach the capsule and create large subcutaneous flaps to expose the patella, quadriceps tendon, medial and lateral retinaculum, and

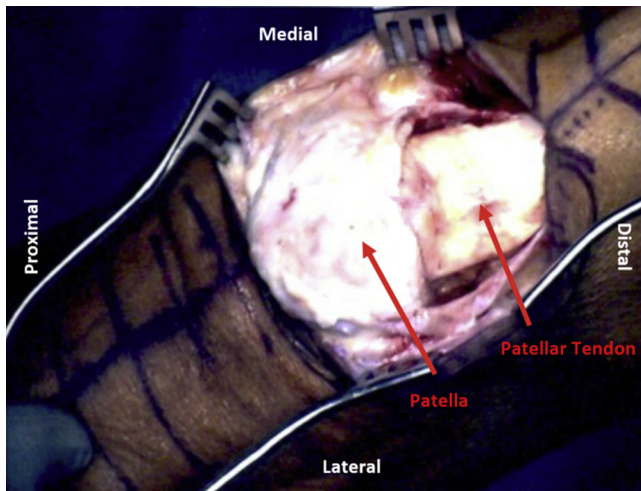


Fig 4. Following the initial longitudinal incision and creation of subcutaneous flaps using electrocautery, the shortened and thickened patellar tendon is demarcated and appreciated.

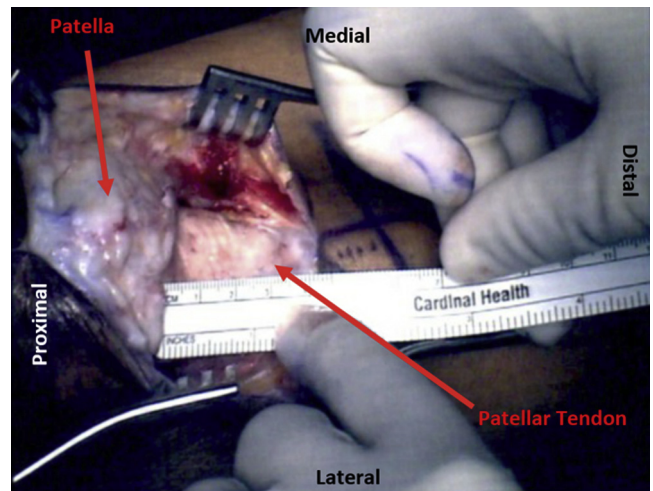


Fig 5. The patellar tendon was tensioned at 30° flexion with a proximal pull on the patella, and the length of the patellar tendon is measured using a ruler.

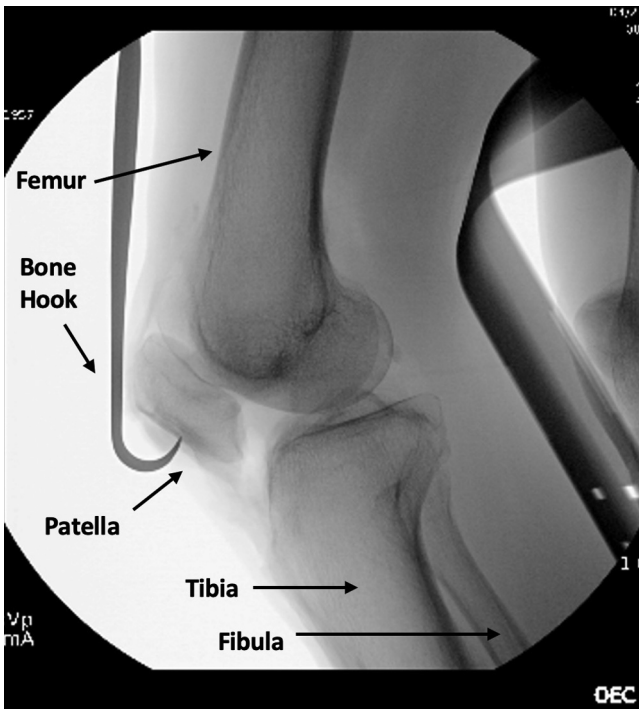


Fig 6. The patella is pulled proximally to put the patellar tendon under tension, and fluoroscopy (lateral view) with the knee at 30° flexion is used to determine the true length of the patellar tendon intraoperatively.

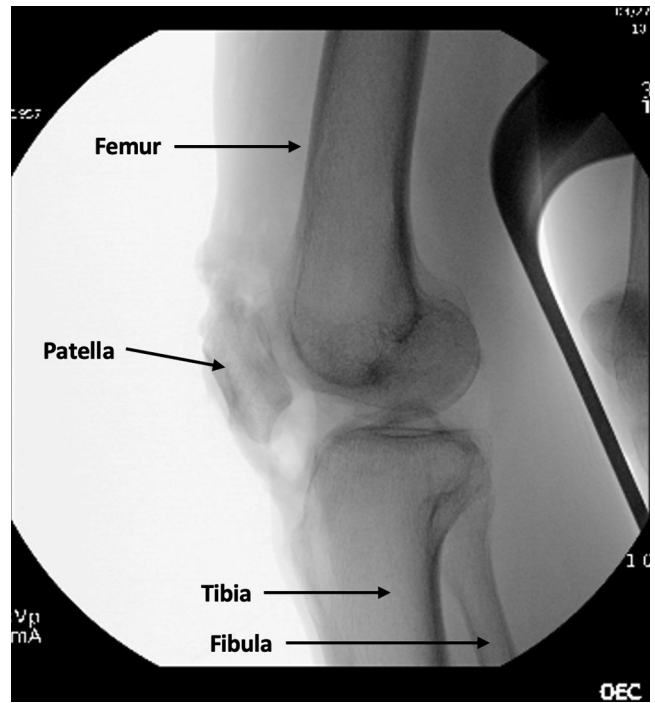


Fig 8. Intraoperative fluoroscopy (lateral view) at 30° flexion confirms improved patellar height following patellar tendon lengthening.

patellar tendon (Fig 4). Typically, a thin film of fibrous tissue is identified superficial to the patella covering the gap between the quadriceps tendon and the patella—this can be incised longitudinally.

Assessment

The terminal end of viable quadriceps tendon is identified. The superior pole of the patella is debrided, and a measurement is made between the 2 structures. The knee is placed at 30° of flexion and proximal

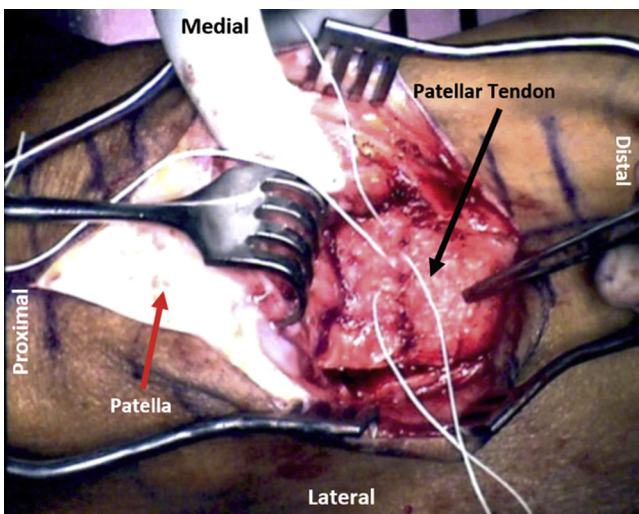


Fig 7. After creating anterior and posterior flaps with sharp dissection, apposition of limbs is performed and secured using high-strength polyethylene sutures, lengthening the patellar tendon. Three locking stitches across the width of the tendon ensure fixation.

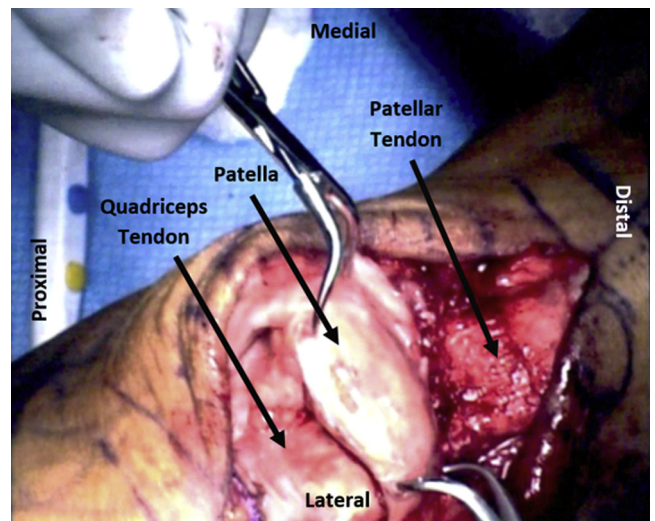


Fig 9. After lengthening the patellar tendon, the gap between the superior pole of the patella and the quadriceps tendon is reassessed. By lengthening the patellar tendon, we appreciate reduction of quadriceps tendon to the patella.

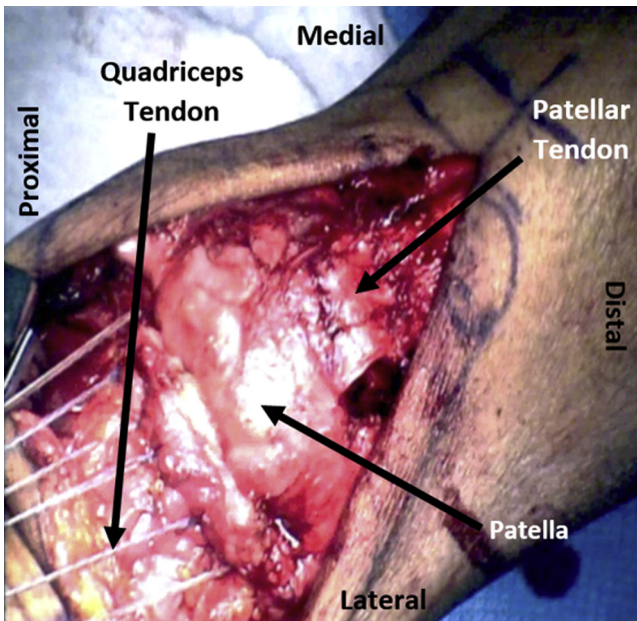


Fig 10. Completed quadriceps tendon reapproximation and repair to the superior pole of the patella prior to bioinductive implant placement. High-strength polyethylene sutures via all-suture anchors are used to secure the quadriceps tendon to the superior pole of the patella.

traction is placed on the patella, tensioning the patellar tendon with the use of a bone hook. True length of the patellar tendon is measured with a ruler intra-operatively as well as fluoroscopically (Figs 5 and 6). The difference between this length on the operative and contralateral legs is calculated.

Open Patellar Tendon Lengthening

Patellar tendon lengthening is performed to address the patella baja and thickened patellar tendon. Lateral

and medial aspects of the patellar tendon are identified, and patellar tendon length is measured using a ruler. The knee is placed at 30° of flexion. By using a 15-blade with the patellar tendon on tension, the anterior 50% of the patellar tendon is sharply elevated from the tibial tubercle proximally to the inferior pole of patella. The posterior 50% of patellar tendon is then detached from the inferior pole of patella. It is important to do this carefully and slowly with sharp dissection and maintenance of the appropriate line in the sagittal plane. Lysis of adhesions and synovectomy of the joint are performed, and the patella is mobilized proximally. Using high-strength polyethylene sutures, patellar lengthening was performed with apposition of limbs as needed to achieve adequate length (Fig 7). Three locking stitches are placed across the width of the patellar tendon to ensure fixation. Restored patellar height is assessed using fluoroscopy (Fig 8). Our goal is to achieve at least 50% apposition of the tendon edges. If significantly less than 50% of apposition is needed to restore patellar height, back-up augmentation with the use of a semitendinosus allograft can be performed (see the section “Allograft Augmentation” to follow).

Open Quadriceps Tendon Repair

Attention is then turned to the proximal end of the extensor mechanism (Fig 9). Allis clamps are placed on the quadriceps tendon, and the tissue is pulled distally. Lysis of adhesions in the midhigh is performed slowly and carefully using Metzenbaum scissors and a Cobb elevator. Should the quadriceps tendon not be of adequate length to primarily reach the superior pole of the patella in full extension, a V-Y quadricepsplasty may be performed to increase tendon length. A V-shaped incision in the quadriceps tendon is made,

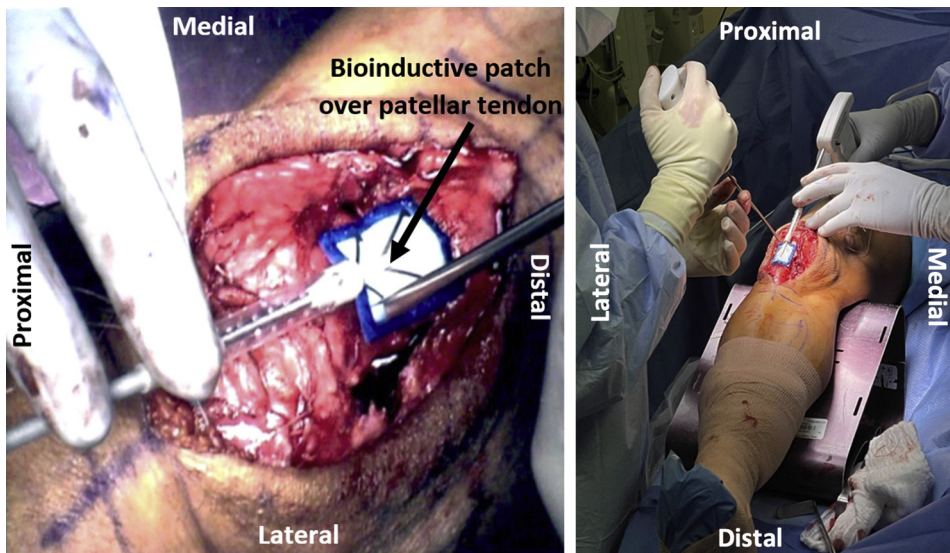


Fig 11. With the leg at 30° of flexion, a bioinductive implant is placed at the location of the anterior-posterior lengthening of the patellar tendon. The implant is secured using soft-tissue staples.

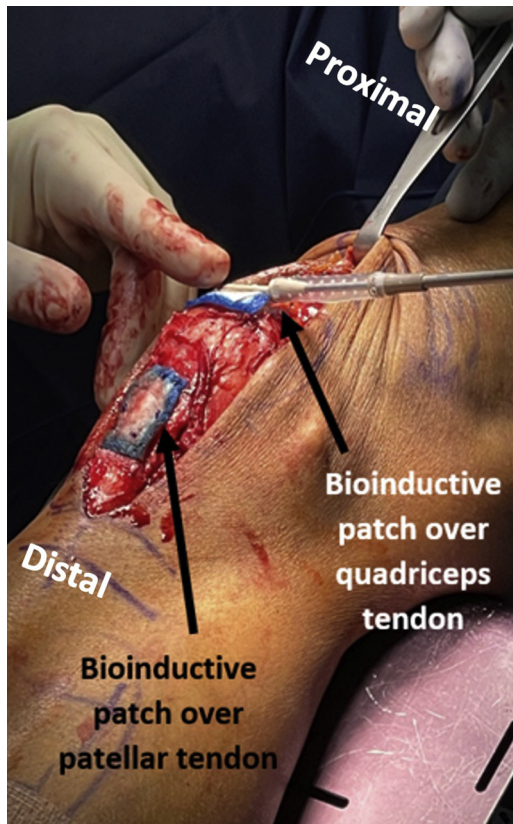


Fig 12. With the leg at 30° of flexion, a bioinductive implant is placed directly over the bone-tendon junction at the superior pole of the patella extending proximally into the quadriceps tendon. This patch is stabilized with 2 bone staples in the patella and multiple soft-tissue staples in the quadriceps tendon.

and then the broad base of the V is advanced into the defect. This is done through sharp dissection at the apex and then repaired using high-strength polyethylene sutures. Once it is determined that the quadriceps tendon is of appropriate length and is competent to

handle attachment to the proximal aspect of patella, the superior pole of the patella is thoroughly debrided with a 15-blade and a series of rongeurs and curettes. A Burr is used to create a bleeding surface, and 3 double-loaded high-strength anchors are placed across the superior pole of the patella. We typically use an all-suture anchor that requires only 2.8 mm of space to help minimize iatrogenic fracture (2.8-mm Q-FIX; Smith & Nephew, Andover, MA) as well as to preserve bone stock in the remainder of the patella should any allograft augmentation be required. Suture anchor fixation allows for a biomechanically accurate repair.¹⁴ One strand of each suture pair would serve as a post and the other would be then whipstitched diffusely into the tendons.

With the leg in extension, the quadriceps tendon is subsequently secured to the proximal pole of the patella by sequentially tying the suture pairs while an assistant pulls distally on the remaining suture pairs. Procedure should result in reduction of quadriceps tendon to the superior pole of the patella and flexion of the knee to 75 to 90° without micromotion at the superior pole of patella. High-strength polyethylene sutures are used for epitendinous repair using periosteum of patella and remnant tissue from peritenon on the patella (Fig 10).

Biological Augmentation

Due to the chronic nature of the injury, as well as the tenuous tissue involved, augmentation with bioinductive implants (REGENETEN; Smith & Nephew) is performed to aid in healing. A bioinductive implant (medium or large) is placed over the location of the anterior-posterior lengthening of the patellar tendon and secured with soft tissue staples (Fig 11). Similarly, the quadriceps repair is augmented with the use of another bioinductive implant placed directly over the bone-tendon junction (Fig 12). This patch is stabilized with 2 bone staples in the bone and multiple soft-tissue

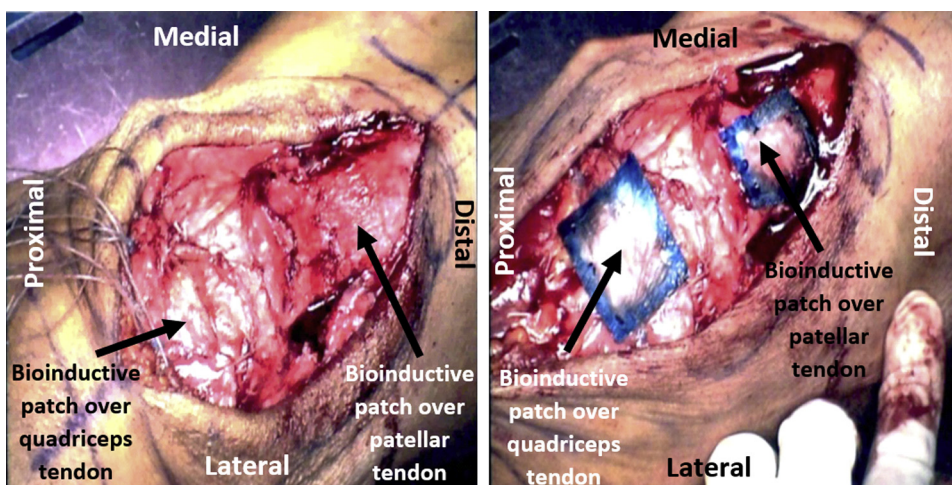


Fig 13. View of both the completed patellar tendon lengthening and quadriceps tendon repair (left) and the placement of bioinductive implants over these repairs (right).

Table 2. Additional Advantages and Disadvantages of Our Technique

Advantages	Disadvantages
<ul style="list-style-type: none"> • More anatomic • Restoration of patellar height reduces extensor lag • Allows for primary repair of the quadriceps tendon • Bioinductive stimulus to healing 	<ul style="list-style-type: none"> • More complex surgery, requires measurement of contralateral limb • Potential disruption of the patellar tendon (which previously was intact but pathologically shortened) • More extensile surgical approach and therefore carries the subsequent risks of a larger incision • Unconventional use of bioinductive implants

staples in the tendon. Closure can begin once both bioinductive patches are secured (Fig 13). A Hemovac drain is placed, and the joint is irrigated with normal saline and then closed sequentially.

Allograft Augmentation

If the patellar tendon is under significant tension after the lengthening procedure and there is concern about the integrity of the tendon, augmentation may be necessary. First, fluoroscopy is used to obtain a lateral view of the knee. A wire is drilled transversely through the midportion of the patella from lateral to medial, and when proper placement is ensured on fluoroscopy, a 5-mm tunnel is reamed over the wire. The anterior tibialis muscle is lifted off of the lateral tibia. Another wire is placed in the tibia from lateral to medial at the level of the tibial tubercle posterior to the tubercle, fluoroscopy is used to confirm proper wire placement, and a 7-mm tunnel is over-reamed. Passing sutures are placed through the tunnel. A semitendinosus allograft is whipstitched on both ends and is then passed through the patellar tunnel. One limb of the graft is passed on

each side of the tibial tunnel. Similar to the tensioning of the patellar tendon, both ends of the graft in the tibial tunnel are then crossed over and tensioned at 30° of flexion. The high-strength sutures from the previous quadricep repair are then also passed through the tibial tunnel. A 7 × 25-mm PEEK (polyether ether ketone) screw secures the graft, and the suture ends are tied over a bone bridge for additional fixation.

Postoperative Rehabilitation

Due to the chronicity of the injury, complexity of this procedure, and delicacy of the tissues involved, patients’ rehabilitation includes both extensive immobilization and subsequent physical therapy. Initially, patients should be non-weight-bearing, and their leg should be placed in a well-padded cylinder cast in full extension for 2 weeks. After week 2, compliant patients can transition to a hinged-knee brace locked in extension. If there is concern for non-compliance, a new cylinder cast can be placed after the incision is inspected. Full extension without range of motion is maintained for approximately 8 weeks following surgery.

Fig 14. Preoperative (left) and 6-months postoperative (right) lateral radiographs revealing improved patellar height. Both radiographs were with the knee at 30° flexion to ensure accurate comparison.

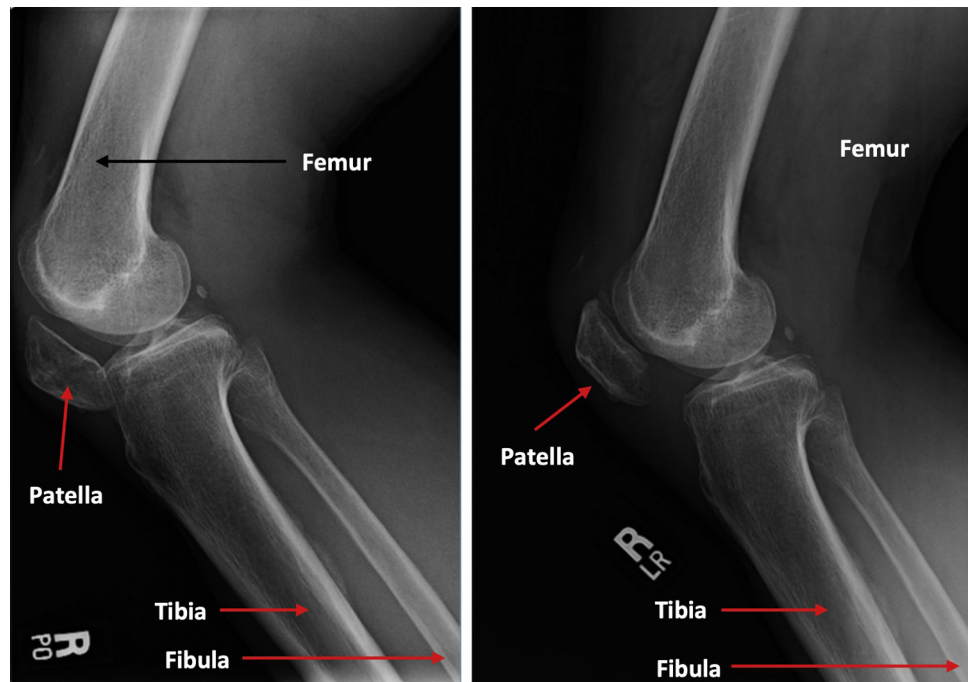




Fig 15. Preoperative (left) and 6 months' postoperative (right) views of the leg revealing improved active extension. Approximately 16 weeks following surgery, this patient exhibited improved active extension and no extensor lag.

Gradual range of motion begins at this point (first 2 weeks: 0-30° motion, following 2 weeks: 0-60° motion, and so forth), and the patient can wean out of the brace at 12-16 weeks once quadriceps control is demonstrated. During the immobilization period, physical therapy should only allow for hip and core strengthening. By 12 weeks' postoperatively, patients should have 25% patellar mobilization through manipulation during physical therapy. By 18 weeks, patellar mobilization should be 50%. Physical therapy should also include ipsilateral quadriceps strengthening, but open-chain exercises are avoided for the first 4 months. Patients can return to high-impact activities like running at 6 months.

Discussion

Our surgical technique prioritizes anatomical restoration of patellar height and augments healing potential with bioinductive implants. Other published techniques for surgical management of chronic quadriceps tendon ruptures involve allograft reconstruction, including tibialis anterior, Achilles tendon, and semitendinosus allografts.¹⁵⁻¹⁷ However, these reconstructions often fail to first restore proper extensor mechanism physiology. When restoration of patellar height is at the forefront of the surgical plan, the native quadriceps tendon can potentially be reattached despite the retraction that often accompanies chronic injury. Eliminating the

need for an allograft in quadriceps tendon reconstruction reduces variables in the healing process.

It is important to note limitations to this surgical approach. Our technique was developed after observing severe patella baja and an abnormally thickened patellar tendon; therefore, a thickened patellar tendon serves as a requirement for this procedure or there will not be sufficient tissue to lengthen the tendon in the fashion described. Further, the dissection of the patellar tendon is typically discouraged given concerns of disrupting integrity and/or vascularity.⁸ However, the bioinductive implants work in conjunction with native tendon biology and stimulate robust healing; although, higher level research is required to support this indication. Nevertheless, a risk of this procedure is potential disruption of the patellar tendon, which previously was intact, but pathologically shortened. Addressing the patellar tendon also requires a more extensile surgical approach and the inherent risks that come with a larger incision. Suture technique could be modified to utilize alternative procedures that have contributed to the successful repair of quadriceps tendon, like double-row suture anchor fixation or a "chariot suture technique."^{18,19} Additional advantages and disadvantages of the technique are presented in [Table 2](#).

This technique effectively restores patellar height and improves extensor lag ([Figs 14 and 15](#)). When other techniques are employed, large extensor lags are

observed. For example, in one study, the use of an Achilles tendon bone-block allograft resulted in a 15° extensor lag 5 months following surgery and a 10° extensor lag 9 months following surgery.¹⁶ Our surgical technique—which is grounded in restoration of anatomical mechanics and biology—improves extensor mechanism function and therefore enhances patients' mobility and quality of life. Although this is a difficult problem to treat, we believe that our technique addresses some shortcomings of previous approaches and successfully contributes to the armamentarium of surgical technique.

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