Technical Note

Quadriceps Tendon Repair Using Double-Row Suture Anchor Fixation

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Abstract: Quadriceps tendon ruptures compromise the knee extensor mechanism and cause an inability to ambulate and significant functional limitations. Therefore, the vast majority of quadriceps tendon ruptures are indicated for operative intervention to restore patient mobility and function. Although these injuries were traditionally repaired using a transosseous repair technique, recent literature has shown that suture anchor repair may offer biomechanical advantages. Additionally, research in other areas of orthopaedics has found that a double-row suture anchor construct can offer additional biomechanical strength to tendinous repair. This technical note describes a safe and effective quadriceps tendon repair using a double-row suture anchor construct.

The knee extensor mechanism is a vital structure for proper lower-extremity mechanics. Injuries to the extensor mechanism prevent the quadriceps muscles from providing active knee extension, compromising overall knee stability and ambulation; thus, nearly all complete disruptions require operative repair. Quadriceps tendon ruptures are the second most common knee extensor mechanism injury and occur at increased frequencies in patients with gout, diabetes, or other endocrinopathies.[1,2] The preferred repair construct for quadriceps tendon tears remains a matter of debate.

Acute quadriceps tendon ruptures are frequently addressed via 1 of 2 repair techniques: transosseous suture repair or suture anchor fixation. Multiple biomechanical studies have shown suture anchor fixation to be superior to transosseous repair regarding ultimate load to failure, gap formation, cyclic displacement, and overall construct stiffness.[3,4] Single-row suture anchor fixation has most commonly been described; however, double-row techniques have been described using proximal and distal rows in the literature.[5] The available data supporting this technique are currently sparse. Achieving a stiff repair construct with minimal gapping and high ultimate load to failure is critical because patients with rerupture of a quadriceps tendon repair have significantly worse long-term functional outcomes.[2]

Numerous studies have documented the biomechanical superiority of double-row suture anchor repair for rotator cuff tears, reproducibly showing decreased gap formation and increased load to failure.[6-8] Double-row repairs have also been described for subscapularis tears, shoulder capsulolabral repair, medial epicondylitis, and hip abductor repair with varying results.[9-12] Conceptually, double-row repairs increase construct stiffness, better re-create broad anatomic footprints, and provide compression of tendon to bone via suture bridges. Despite this, there is a paucity of data describing significant clinical benefits to double-row repairs. Potential drawbacks include increased technical difficulty, increased operative time, increased expense, and crowding of suture anchors.

In this article, we describe a double-row quadriceps tendon repair using proximal and distal rows. A detailed description of our technique can be viewed in Video 1.

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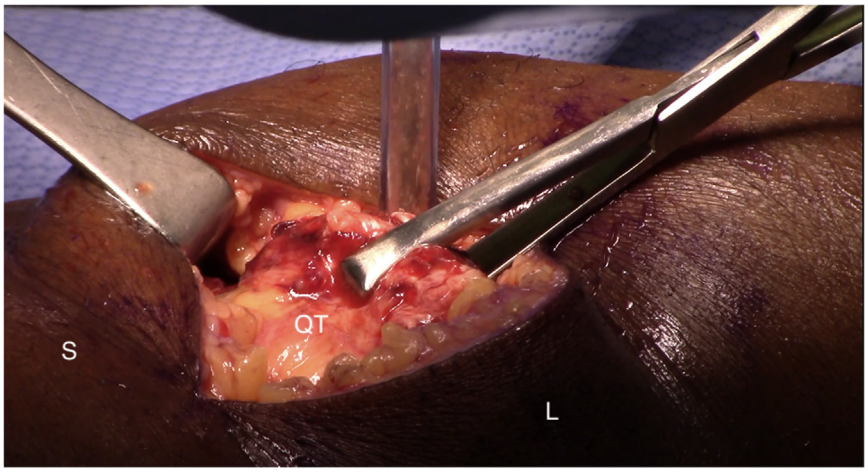

Fig 1. View from the lateral side of the patient, positioned supine, with his right leg draped free. The quadriceps tendon (QT) tear has been identified, clamped, and mobilized. (L, lateral; S, superior.)

Surgical Technique

Preoperative Evaluation, Imaging, and Surgical Indications

Patients presenting with quadriceps tendon tears require a full history and physical examination. Tears often occur after an acute, traumatic event typically involving an eccentric contraction with immediate knee pain and swelling. The hallmark physical examination finding is the inability to perform a straight-leg raise or actively extend the knee when supine on the examination table, and a gap can often be palpated at the superior pole of the patella.[13] Although the history and physical examination findings are often sufficient in making the diagnosis, imaging such as radiography, ultrasound, or magnetic resonance imaging can be used to confirm the diagnosis. Because a complete quadriceps tendon tear constitutes a disruption of the knee extensor mechanism, surgical intervention is indicated to restore ambulation and function.

Anesthesia and Patient Positioning

Surgical consent is obtained from all patients per hospital protocol, and the affected side is confirmed and initialed in the preoperative area. A preoperative ultrasound-guided femoral nerve block is administered by anesthesia to assist with postoperative pain control. The patient is transported to the operating room, and general anesthesia and preoperative antibiotics are administered. The patient is positioned supine on the table, and a bump is placed under the ipsilateral hip to internally rotate the patella so it is facing directly anterior. A tourniquet may be placed to minimize blood loss and maximize visualization. An examination with the patient under anesthesia is performed to assess the location of the patella and determine the amount of gapping of the quadriceps tendon from the superior pole of the patella. The leg is then raised in a leg holder and prepared with a combination of chlorhexidine and alcohol.

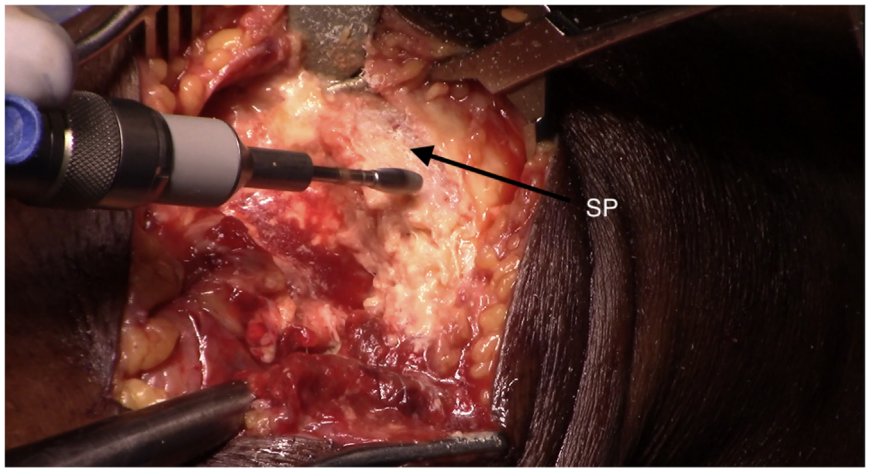

Fig 2. View from the lateral side of the patient, positioned supine, with his right leg draped free. The superior pole (SP) of the patella is prepared for suture anchor placement by removing the soft-tissue remnant and using a burr to create a trough of bleeding bone.

Table 1. Pearls and Pitfalls of Double-Row Quadriceps Tendon Repair

Pearls	Pitfalls
Using a tension-slide technique allows for adequate tensioning and tendon reduction prior to tying the knot.	Using multiple suture anchors can make it difficult to ensure that there are adequate bone bridges between anchors.
The technique uses a positive-stop drill instead of freehand drilling or a punch to avoid risking damage to the articular cartilage.	Thorough debridement of soft tissue prior to anchor placement is critical to avoid soft-tissue interposition between the suture anchor and bone.
The patellar bone can be very hard and require tapping or over-tapping to limit anchor breakage.	The surgeon should ensure that the drill trajectory does not migrate posterior in the patella and compromise patellar cartilage.

Approach and Preparation

The borders of the patella are identified and marked with a marking pen, and the distal aspect of the quadriceps tendon tear is palpated to determine the length of the incision. The incision must allow access to the distal tendinous portion of the quadriceps tendon down to the middle half of the patella and is made in the midline of the extremity. Dissection is carried down through the subcutaneous tissues to the level of the quadriceps tendon, and a copious hematoma is typically encountered. The distal aspect of the quadriceps tendon is then exposed and inspected, with any nonviable tissue resected to the level of the healthy quadriceps tendon. The distal end of the tendon may be grasped with a clamp to test the excursion of the tendon (Fig 1). Attention is then turned to the patella and exposure of the superior pole. Any remnant soft tissue is removed from the superior pole, and a burr is used to prepare a trough of bone for anchor placement (Fig 2). Additionally, dissection is carried halfway down the anterior face of the patella to prepare for the double-row construct.

Anchor Placement and Tendon Fixation (Medial Row)

After preparation of the superior pole of the patella, the location for placement of 2 anchors is determined by dividing the superior pole into thirds and placing the anchors equidistant from the center of the patella. Pilot holes are drilled using a drill guide and positive-stop drill (Table 1). The holes are then tapped, followed by placement of 2 suture anchors double loaded with suture tape (PEEK [polyether ether ketone] Corkscrew FT; Arthrex, Naples, FL) (Fig 3). The suture strands are separated, and a free needle is used to pass the suture up and down the lateral aspect of the ruptured quadriceps tendon in Krackow fashion, entering and exiting at the ruptured face of the tendon. The other end of the suture is then passed from inferior to superior through the quadriceps tendon to prepare for a tension-slide tying technique. The unused loaded suture tape is passed through the quadriceps tendon in mattress fashion, allowing for backup fixation of the repair. This is then repeated on the medial side of the tendon using the medial anchor (Fig 4). The sutures are tied using a tension-slide technique to reduce and secure the quadriceps tendon back to the superior pole of the patella.

Lateral-Row Fixation

The anterior aspect of the patella is then exposed, and 2 locations for anchor placement are identified in the middle half of the patella, in line with the anchors in the superior pole (Fig 5). A pilot hole is drilled and

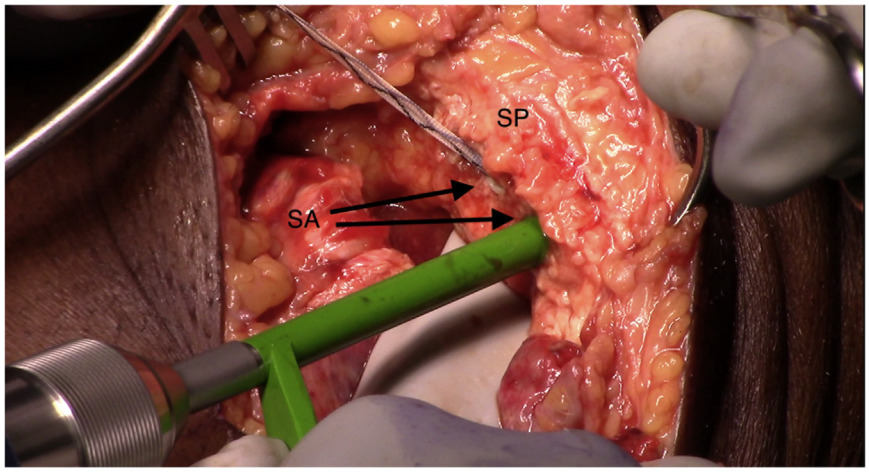

Fig 3. View from the lateral side of the patient, positioned supine, with his right leg draped free. Two suture anchors (SA) are placed into the superior pole of the patella (SP), equidistant from the center of the patella, ensuring to leave adequate space between the anchors.

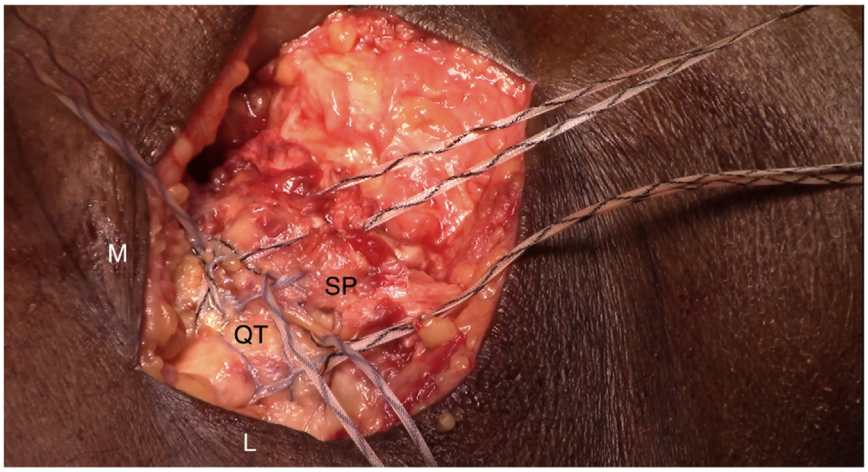

Fig 4. View from the lateral side of the patient, positioned supine, with his right leg draped free. The quadriceps tendon (QT) is secured using medial (M) and lateral (L) Krackow stitches, and the tendon is secured to the superior pole of the patella (SP).

tapped into the patella to prepare for anchor placement. Two sutures from the contralateral anchor and 1 from the ipsilateral anchor are then loaded into an additional anchor (3.5-mm PEEK SwiveLock; Arthrex) and tensioned, and the anchor is impacted into the patella. This is repeated on the contralateral side of the patella. This completes the double-row construct, allowing for reduction of the tendon to the superior pole with tissue compression and backup fixation provided by the lateral row (Fig 6, Table 2). The knee is then taken through a gentle range of motion to visualize the quadriceps tendon moving with the patella without any gapping. The knee joint is thoroughly irrigated, the retinaculum is inspected, and any tearing is repaired with additional nonabsorbable sutures, followed by standard wound closure.

Postoperative Care

The patient is placed into a knee brace locked in 0° of extension, and an ice machine is placed over the operative area. The patient is allowed weight bearing as tolerated with the brace on and locked in extension at all times. The allowed range of motion is gradually increased over a period of 12 weeks, after which the patient may discontinue brace wear.

Discussion

Quadriceps tendon ruptures are a rare but devastating injury requiring operative intervention to restore function to the extensor mechanism of the knee. Prompt diagnosis and repair are essential for maximizing patient outcomes because repair of chronic tears increases both the technical difficulty of the operation and the chance of a poor outcome.[14] There are multiple techniques used to repair quadriceps tendon ruptures, with a systematic review of clinical outcomes after repair of quadriceps tendon ruptures noting that a transosseous tunnel technique was the most commonly used technique.[15] However, recent investigations have

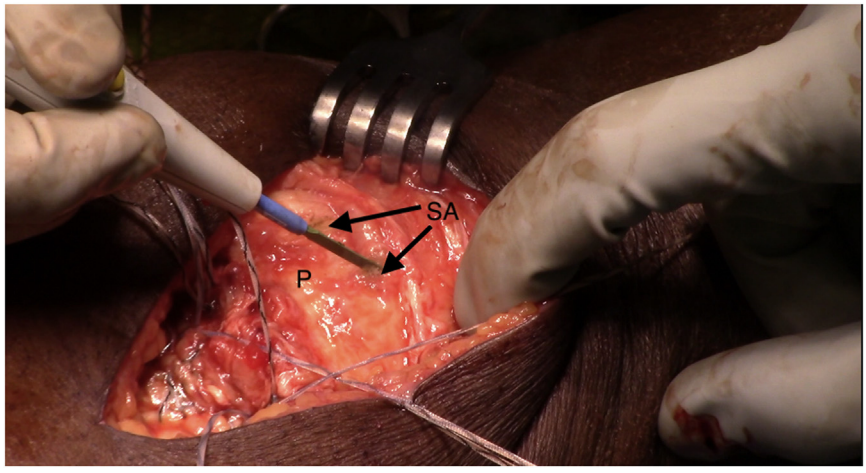

Fig 5. View from the lateral side of the patient, positioned supine, with his right leg draped free. Two locations for suture anchors (SA) are identified on the anterior face of the patella (P), one-third of the way down the face of the patella and equidistant from the center of the patella, for placement of the double-row anchors.

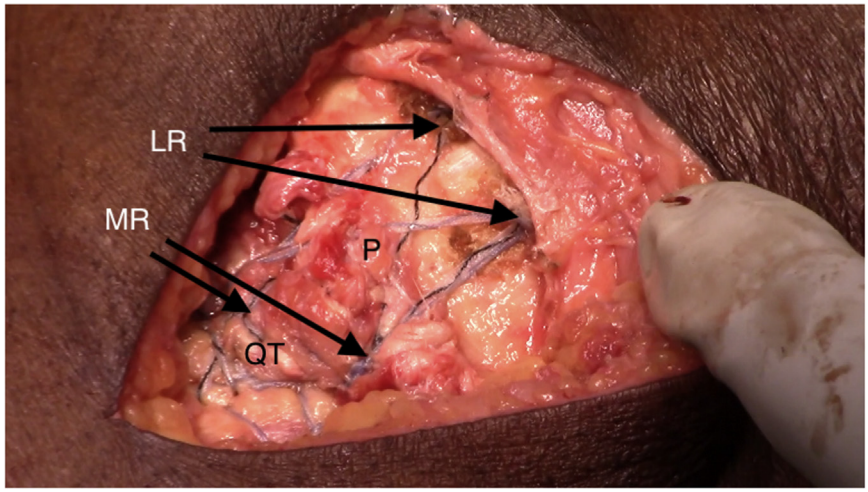

Fig 6. View from the lateral side of the patient, positioned supine, with his right leg draped free. Final construct showing a successful double-row repair of the quadriceps tendon (QT) using a medial row (MR) and lateral row (LR) into the patella (P).

looked more closely at the use of suture anchor repair in the setting of quadriceps tendon rupture.

Multiple cadaveric studies have been conducted comparing the fixation strength of transosseous tunnels versus suture anchor repair of quadriceps tendon ruptures. Sherman et al.[16] performed a biomechanical analysis on cadaveric knees and found that there was significantly less gap formation with cyclic loading in the suture anchor group. Petri et al.[4] examined 30 cadaveric knees and found that suture anchor repair yielded significantly less gap formation and had a higher ultimate tensile load to failure compared with a transosseous tunnel technique. When examining the mode of failure between groups, they found that titanium anchors mostly failed by pulling out of bone whereas hydroxyapatite anchors' mode of failure was suture breakage at the anchor eyelet. An advantage of the presented double-row technique is the availability of backup fixation from the double row in the event of anchor failure. Additionally, research in other areas, primarily in the areas of rotator cuff repair, has shown the biomechanical strength of double-row constructs over single-row repair.[17]

Table 2. Advantages and Disadvantages of Double-Row Quadriceps Tendon Repair

Advantages
Broader restoration of anatomic footprint
Smaller incision and avoidance of violating patellar tendon while passing sutures
Potentially improved biomechanical properties
Disadvantages
Additional holes drilled into patella compared with single-row technique
Increased cost
Increased suture anchor traffic

Clinical results after suture anchor repair of quadriceps tendon ruptures appear to show favorable patient outcomes. In a prospective, multicenter study of patients undergoing suture anchor repair of quadriceps tendon ruptures, Mille et al.[18] found that all patients were able to return to their preinjury level of functioning at a mean time of 3 months, with 6-month magnetic resonance imaging studies revealing good tendon healing in all cases. Brossard et al.[19] conducted long-term follow-up of patients after suture anchor fixation and found that most patients did not have any extensor lag and subjective scores remained satisfactory at 7 years' follow-up. Although the clinical results after this procedure are promising, there is an overall lack of long-term prospective studies evaluating the use of anchor repair of quadriceps tendon injuries and the best method for fixation.

Although there appear to be biomechanical advantages to suture anchor repair of quadriceps tendons, clinical differences between constructs are lacking. A pilot study comparing transosseous sutures versus anchors was unable to show a clinical difference between groups among 27 patients, with good to excellent outcomes regardless of repair method.[20] Further long-term investigations comparing these techniques, as well as emerging techniques as presented in this article, will be essential in providing patients with the best chances of tendon healing and favorable long-term outcomes.

In conclusion, the presented technique offers a unique approach to quadriceps tendon injuries using concepts previously shown in the orthopaedic literature. Suture anchor repair offers potential biomechanical advantages over traditional transosseous tunnel repair, and the double-row construct provides backup fixation and increases the soft-tissue contact

area and compression at the superior pole of the patella.

References

1. Melvin JS, Mehta S. Patellar fractures in adults. *J Am Acad Orthop Surg* 2011;19:198-207.
2. Negrin LL, Nemecek E, Hajdu S. Extensor mechanism ruptures of the knee: Differences in demographic data and long-term outcome after surgical treatment. *Injury* 2015;46:1957-1963.
3. Kindya MC, Konicek J, Rizzi A, Komatsu DE, Paci JM. Knotless suture anchor with suture tape quadriceps tendon repair is biomechanically superior to transosseous and traditional suture anchor-based repairs in a cadaveric model. *Arthroscopy* 2017;33:190-198.
4. Petri M, Dratzidis A, Brand S, et al. Suture anchor repair yields better biomechanical properties than transosseous sutures in ruptured quadriceps tendons. *Knee Surg Sports Traumatol Arthrosc* 2015;23:1039-1045.
5. Hart ND, Wallace MK, Scovell JF, Krupp RJ, Cook C, Wyland DJ. Quadriceps tendon rupture: A biomechanical comparison of transosseous equivalent double-row suture anchor versus transosseous tunnel repair. *J Knee Surg* 2012;25:335-339.
6. Smith CD, Alexander S, Hill AM, et al. A biomechanical comparison of single and double-row fixation in arthroscopic rotator cuff repair. *J Bone Joint Surg Am* 2006;88:2425-2431.
7. Kim DH, Elattrache NS, Tibone JE, et al. Biomechanical comparison of a single-row versus double-row suture anchor technique for rotator cuff repair. *Am J Sports Med* 2006;34:407-414.
8. Meier SW, Meier JD. The effect of double-row fixation on initial repair strength in rotator cuff repair: A biomechanical study. *Arthroscopy* 2006;22:1168-1173.
9. Cabarcas BC, Garcia GH, Liu JN, Gowd AK, Romeo AA. Double-row arthroscopic subscapularis repair: A surgical technique. *Arthrosc Tech* 2018;7:e805-e809.
10. Yousif MJ, Bicos J. Biomechanical comparison of single- versus double-row capsulolabral repair for shoulder instability: A review. *Orthop J Sports Med* 2017;5:2325967117742355.
11. Kahlenberg CA, Nwachukwu BU, Jahandar H, Meyers KN, Ranawat AS, Ranawat AS. Single- versus double-row repair of hip abductor tears: A biomechanical matched cadaver study. *Arthroscopy* 2019;35:818-823.
12. Wu VJ, Thon S, Finley Z, et al. Double-row repair for recalcitrant medial epicondylitis. *Orthop J Sports Med* 2019;7:2325967119885608.
13. Ilan DI, Tejwani N, Keschner M, Leibman M. Quadriceps tendon rupture. *J Am Acad Orthop Surg* 2003;11:192-200.
14. Rocha de Faria JL, Barroso de Matos M, de Araujo Barros Cobra HA, et al. Surgical treatment of chronic rupture of the quadriceps using a modified Pulvertaft weave technique. *Arthrosc Tech* 2019;8:e1163-e1169.
15. Ciriello V, Gudipati S, Tosounidis T, Soucacos PN, Giannoudis PV. Clinical outcomes after repair of quadriceps tendon rupture: A systematic review. *Injury* 2012;43:1931-1938.
16. Sherman SL, Copeland ME, Milles JL, Flood DA, Pfeiffer FM. Biomechanical evaluation of suture anchor versus transosseous tunnel quadriceps tendon repair techniques. *Arthroscopy* 2016;32:1117-1124.
17. Wall LB, Keener JD, Brophy RH. Double-row vs single-row rotator cuff repair: A review of the biomechanical evidence. *J Shoulder Elbow Surg* 2009;18:933-941.
18. Mille F, Adam A, Aubry S, et al. Prospective multicentre study of the clinical and functional outcomes following quadriceps tendon repair with suture anchors. *Eur J Orthop Surg Traumatol* 2016;26:85-92.
19. Brossard P, Le Roux G, Vasse B, Orthopedics, Traumatology Society of Western France (SOO). Acute quadriceps tendon rupture repaired by suture anchors: Outcomes at 7 years' follow-up in 25 cases. *Orthop Traumatol Surg Res* 2017;103:597-601.
20. Plesser S, Keilani M, Vekszler G, et al. Clinical outcomes after treatment of quadriceps tendon ruptures show equal results independent of suture anchor or transosseus repair technique used—A pilot study. *PLoS One* 2018;13:e0194376.