Technical Note

Bicortical Titanium Tenodesis Button With Double-Row Fixation for the Treatment of Proximal Rectus Femoris Avulsion: Review of Literature and Surgical Technique

Victor Hoang, D.O., Colin Brown, B.S., Keith Kotecki, D.O., and Randa Bascharon, D.O.

Abstract: In adult populations, rectus femoris avulsions are reported in professional soccer and football players but are noted to be exceptionally rare. No gold standard or recommendations exist for this injury; however, in cases of avulsion at the anterior inferior iliac spine, positive outcomes appear to result from rest, immobilization, and rehabilitation. Surgery is typically reserved for cases with large retractions of bone fragments or unsuccessful nonoperative treatment. Surgical treatment methods vary from direct suture repair to single- and double-row bone suture placement and even muscle-muscle repair. We present our technique using a bicortical tenodesis button with double-row fixation for the treatment of a severely retracted rectus femoris tendon avulsion in a high-level athlete.

Rectus femoris (RF) avulsion fractures are well documented in athletic adolescent populations and thought to be rare in skeletally mature populations.[1] RF avulsions in adult populations are reported in professional soccer[1-7] and football players[8] but are noted to be exceptionally rare. Although intramuscular quadriceps strains are common, the rarer proximal RF avulsion injury, with a reported incidence of 0.5%, is a more serious injury that can cause significant pain and loss of function in the knee and hip joints.[9]

The RF crosses the hip and knee joints, providing combined hip flexion and knee extension. It is believed that the bi-articular nature of the RF leads to greater strain in eccentric loading, most specifically at the musculotendinous junction.[10,11] The mechanism of injury is commonly seen in athletes who frequently run, jump, or strike a ball.[11] The RF has 2 tendon heads: the direct head, originating in the anterior inferior iliac spine (AIIS), and the indirect head, originating just superior to the acetabular ridge.[11] The indirect head is most commonly involved, but in rare cases, complete avulsion of both heads can occur.[9]

Currently, the consensus seems to be that RF avulsion fractures are best initially managed nonoperatively, with operative procedures reserved for patients who experience reinjury after conservative treatment or experience complete avulsion of both tendon heads in high-level athletes.[3] However, studies have shown an injury recurrence rate as high as 18% in elite-level athletes managed nonoperatively.[8] We present a review of the literature of nonoperative management, operative treatment, and postoperative care options in elite-level athletes with RF avulsion injuries. In addition, we present our surgical technique using a bicortical tenodesis button with double-row fixation for the treatment of a severely retracted RF tendon avulsion in an elite athlete with a successful accelerated return to professional soccer. The unique aspect of the technique is the use of bicortical tenodesis buttons with double-row fixation, which—to our knowledge—has not been previously described.

Technique

Equipment

Table 1 lists the instruments used.

From Valley Hospital Medical Center, Las Vegas, Nevada, U.S.A. (V.H., K.K., R.B.); and Touro University Nevada, Henderson, Nevada, U.S.A. (C.B.).

The authors report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received December 29, 2020; accepted February 15, 2021.

Address correspondence to Colin Brown, B.S., 3463 Procyon St, Unit 164, Las Vegas, NV 89102, U.S.A. E-mail: colbrown@ucdavis.edu

2212-6287/202084
https://doi.org/10.1016/j.eats.2021.02.019

Table 1. Instruments

No. 10 blade
Metzenbaum scissors
Army-Navy retractors
Hibbs retractors
Self-retracting retractors
Freer
High-speed round egg burr
Cobb elevator
Key elevator
Large Hohmann retractor
No. 2 FiberWire
3.2-mm guide pin
2.6 × 7—mm tenodesis titanium button
4.75-mm Biocomposite SwiveLock anchor loaded with FiberWire × 2
4.75-mm tap
No. 2-0 Vicryl and No. 3-0 Monocryl sutures
Ultrasound scanner

Patient Position and Preparation

The patient is positioned supine on the operative table. The hip is prepared and draped in sterile fashion.

Operative Technique

A sterile ultrasound (US) scanner is used to aid in exact identification of the location of the distal retraction of the RF tendon, which is typically found approximately 5 cm distal from the footprint on the AIIS. A longitudinal incision is made from the anterior superior iliac spine distally approximately 10 cm toward the lateral aspect of the patella to find the interval between the sartorius and tensor fascia lata. Careful dissection through subcutaneous tissue is performed using blunt dissection. Care is taken to preserve the branches of the lateral femoral cutaneous nerve. At this time, a sharp incision is made to incise the sartorial fascia. An Allis clamp is used to clamp the fascia, and blunt dissection is performed to elevate the sartorial fascia off the muscle. The sartorius is then carefully retracted medially, and tensor fascia lata, laterally. An Aquamantys bipolar device (Medtronic) is used to carefully coagulate the branches of the lateral femoral circumflex vessels to obtain careful hemostasis because, otherwise, they would be in the field and block the repair. The torn RF tendon is then identified inside the tendon sheath (Fig 1).

The tendon sheath of the RF is carefully incised to free it from surrounding tissue bluntly to properly gain excursion of the tendon so that it can be approximated back to the origin for the repair (Fig 2). At this time, the tendon sheath is followed to the RF origin on the AIIS, as well as the indirect head of the acetabulum. Care is taken to maintain indirect fibers on the acetabulum. The AIIS is dissected from the periosteum, as well as torn remnants of the RF origin (Fig 3).

An Arthrex No. 2 FiberWire is used to secure the RF tendon in Krackow fashion (Fig 4). A drill is then used for the button insertion with a 3.2-mm pin, which is placed on the center of the AIIS from lateral to medial (Fig 5). Care is taken to protect the neurovascular structures medial to the AIIS. The guide pin is then over-drilled to prepare for button placement.

The sutures are placed in an Arthrex 2.6-mm × 7-mm Tenodesis Titanium Button (Fig 6). The button is placed through a previously drilled tunnel and is noted to have flipped; the flipping of the button can be confirmed by direct palpation. The sutures are then tightened, and the tendon is approximated to a prepared footprint. The knee is extended, and the hip is flexed to aid in tendon reduction. At this time, an Arthrex 4.75-mm Biocomposite SwiveLock anchor loaded with FiberTape (Arthrex) is placed just proximal to an EndoButton (Smith & Nephew) after placing the guide pin, drilling, and tapping. Care should be taken to ensure that the drill and SwiveLock anchor are within the AIIS portion of the iliac crest. Additional consideration should be

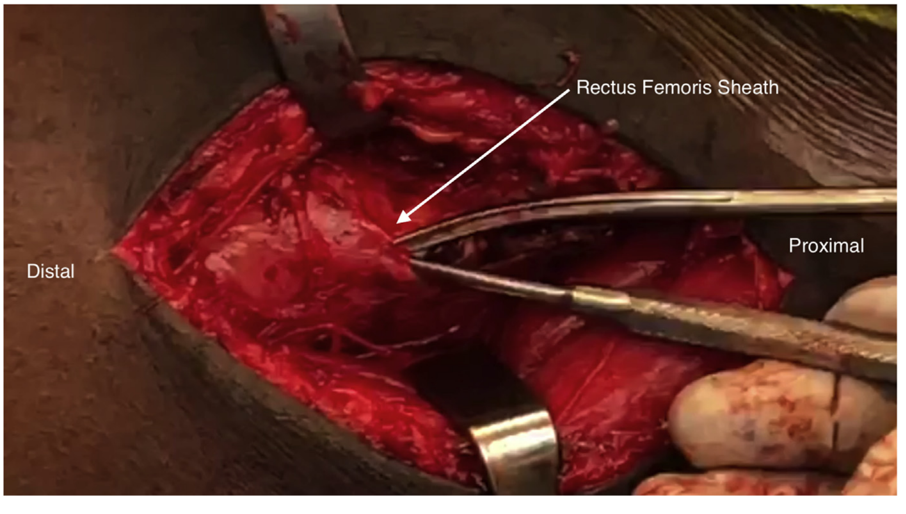

Fig 1. A 6-cm longitudinal incision is created, starting slightly distal and lateral to the anterior superior iliac spine and extending distally following the Smith-Petersen approach. Care should be taken to avoid the lateral femoral cutaneous nerve when using this approach. A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

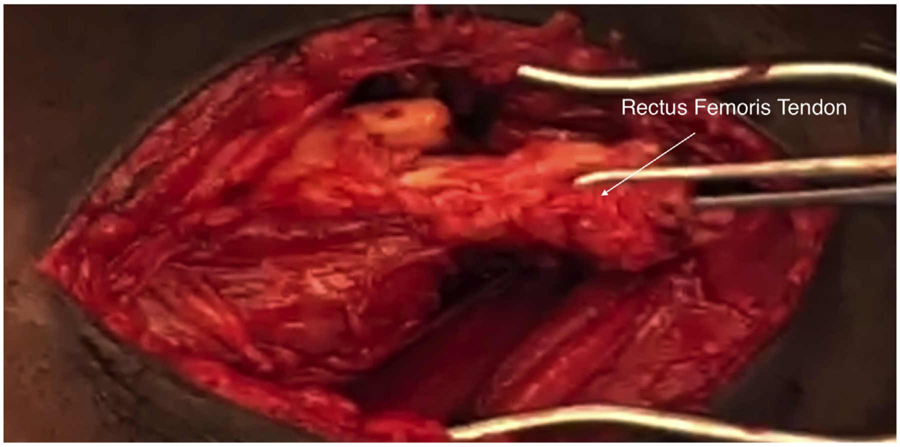

Fig 2. Blunt dissection of the tissue is performed to release the area of adhesions and to visualize the rectus femoris tendon sheath. The tendon sheath is then incised to reveal the ruptured tendon. A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

made to place the anchor away from the EndoButton to prevent convergence (Fig 7). The FiberTape from the SwiveLock anchor is run in a locking fashion through the tendon for additional fixation to secure the tendon origin to the AIIS (Fig 8).

An inferior-row SwiveLock anchor and FiberTapes are run through the proximal tendon and then drilled and tapped 1 cm proximal to the previous SwiveLock anchor. The sutures are secured with another 4.75-mm SwiveLock anchor, creating a double-row construct above the EndoButton (Fig 9). The remaining islet sutures are then tied to the inferior-row sutures to allow for greater bony footprint contact with the tendon.

At this juncture, with the hip in extension, the knee is brought into full flexion to test construct stability, as well as any potential gapping with full knee range of motion and stress on the construct (Video 1). The wound is then thoroughly irrigated with 500 mL of chlorhexidine solution with normal saline. The RF tendon sheath is closed with No. 0 Vicryl (Arthrex) in an interrupted fashion. The interval between the tensor fascia lata and sartorial fascia is closed using No. 0 Vicryl in a running-suture fashion. The skin is closed in a subcutaneous manner with No. 2-0 Vicryl and No. 3-0 Monocryl (Arthrex) is used for final skin and sealed with Dermabond (Johnson & Johnson). Ten milliliters of 0.25% bupivacaine is given for local anesthesia and postoperative pain control.

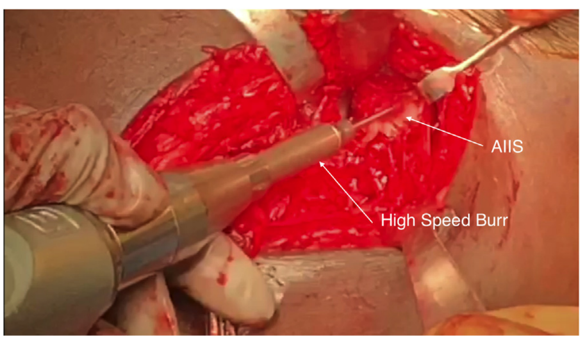

Fig 3. Preparation of the primitive footprint involves removing the soft tissue and using a key elevator and high-speed burr to expose subchondral bone and to create a bleeding bony bed on the rectus femoris footprint. A right hip is shown through the Smith-Petersen approach with the patient in the supine position. (AIIS, anterior inferior iliac spine.)

Postoperative Care

Sterile dressings are applied, and the patient is given postoperative pain-control medication.

Discussion

This article presents a summary of current operative and nonoperative management methods for RF avulsion injuries in the literature and our operative treatment technique for RF avulsion using a double-row bicortical tenodesis button with double-row fixation. To our knowledge, this is the first study to describe the use of a double-row bicortical tenodesis button with double-row fixation for repair of an RF avulsion injury.

We have noted several risks and concerns in using this graft technique for RF avulsion repair (Table 2). Although no research has described the same suture materials and method of RF avulsion repair, successful repair of tibiofibular joint instability without any reported adverse reactions and with increased joint flexibility has been reported.[12]

Currently, no gold standard for treatment or postoperative management exists for RF avulsion injuries. However, various authors seem to agree that prompt and accurate diagnosis is crucial in the management of these patients.[2,13] US has been suggested as a more rapid and inexpensive imaging modality for diagnosis[13]; however, authors have suggested that US lacks the resolution to grade such injuries regardless of skill.[6] However, US could be useful in conjunction with physical examination findings in the on-field diagnosis of RF avulsion injuries to prevent a missed or delayed diagnosis.[1] US provides an early and rapid idea of hematomas and avulsions, which

Fig 4. The rectus femoris tendon is removed from the sheath and cleared of adhesions. A nonabsorbable suture (No. 2 FiberWire) is then passed through the rectus femoris tendon with a Krackow locking stitch technique. A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

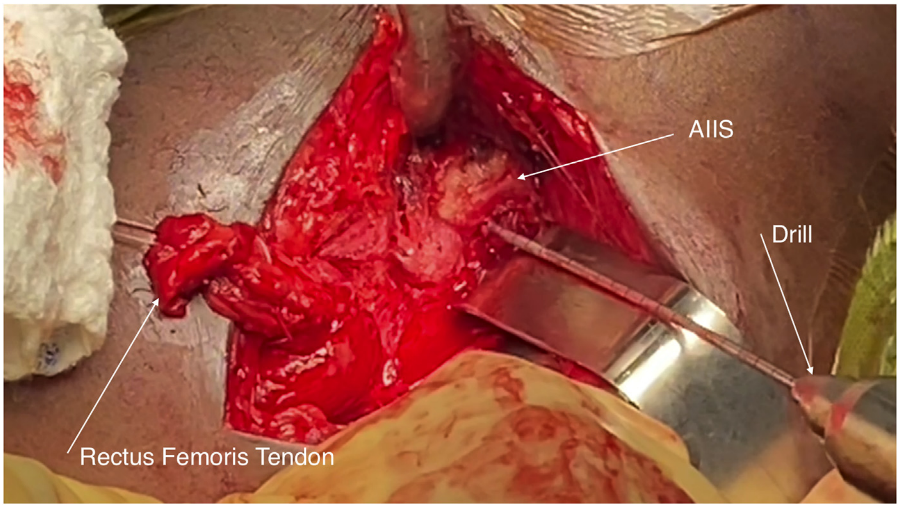

Fig 5. A 3.2-mm guidewire is driven from lateral to medial in a bicortical fashion on the inferior aspect of the anterior inferior iliac spine (AIIS). A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

Fig 6. The sutures are placed in a 2.6-mm × 7-mm Tenodesis Titanium Button. Care is taken to protect the neurovascular structures medial to the anterior inferior iliac spine during button insertion. A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

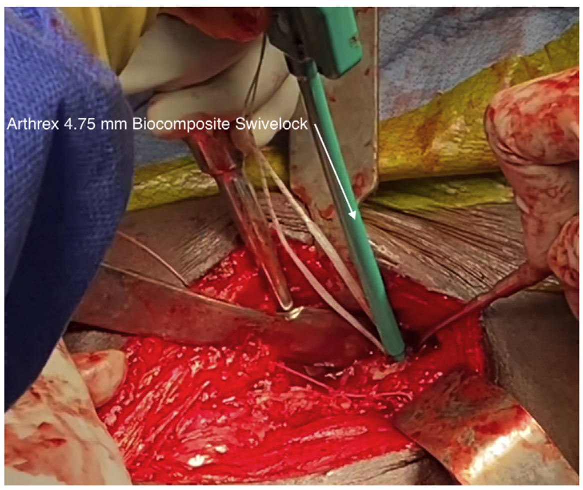

Fig 7. The inferior row is placed using a 4.75-mm Bio-composite SwiveLock anchor loaded with nonabsorbable suture. Care is taken to place the anchor away from the EndoButton to prevent convergence. A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

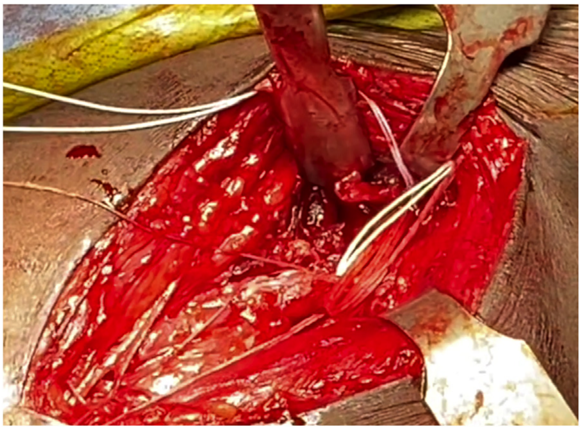

Fig 8. FiberTapes are passed through the rectus femoris tendon in a locking fashion. Retractors are placed to visualize the angle of the anterior inferior iliac spine for anchor placement. A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

could be used to better screen on-field injuries and guide further management. Currently, pelvic magnetic resonance imaging is used as the main diagnostic imaging method for RF avulsion injuries.

Most authors agree that nonoperative management is the most appropriate first-line approach, whereas recommendations for various grades of tear and initial retractions vary. Sonnery-Cottet et al.[3] proposed an algorithm that reserves surgical treatment of RF avulsions for elite athletes who experience reinjury after conservative treatment or those with avulsions of both tendon heads. García et al.[2] suggested that patients with a large initial degree of retraction of the tendon head should forgo conservative management for surgery. We believe the algorithm proposed by Sonnery-Cottet et al., suggestions by García et al., and indications and contraindications outlined by Dean et al.[13] currently describe the best approach to care for this injury.

In the literature, there is great variability in how nonoperative patients are managed, but the outcomes of most patients showed low reinjury rates and a full return to elite-level play.[4,6,8,14] Gamradt et al.[8] conducted the largest study of conservatively managed patients, 16 elite-level American football players, with direct head injuries of the RF and noted a recurrence rate of 18%. Similarly to nonoperative treatments, various surgical methods have been reported in the treatment of RF avulsion fractures. Surgical treatment methods range from direct suture repair[2] to single- and double-row bone suture placement,[5] as well as muscle-muscle repair.[3] The outcomes in surgically managed patients are good, with a low recurrence of injury and full return to elite play, with all methods reported.[2,7,13] After surgical repair of the enthesis involving bone sutures and direct sutures, longer return-to-play times have been observed compared with patients managed nonoperatively,[7,13] with the exception of the study by García et al.,[2] who observed that 9 of 10 surgically managed patients received platelet-rich plasma during recovery. However, Lempainen et al.[5] suggested that the exact site and tendon head involvement are not consistently documented in the literature, thus complicating a comparison of exact methods, postoperative care, and results among studies.

We believe the repetitive explosive hip flexion demands of elite-level athletes experiencing RF avulsion injury warrant the greater operative time and resources for double-row fixation. Sonnery-Cottet et al.[3] suggested that the surgical methods described in the current literature lead to a chronic stress-strain pattern that can explain the longer recovery times and pain commonly reported by surgically managed patients after returning to competitive play. Sonnery-Cottet et al. used a muscle-to-muscle suturing method to integrate the RF into the surrounding quadriceps muscles to avoid this chronic stress pattern. However, 20% of the patients were observed to have a loss in moderate-high quadriceps group strength.[3] Newsham-West et al.[15] showed that the tissue in enthesis repair surgery, seen in direct suture and bone suture repairs, results in fibrous tissue instead of the natural fibrocartilage. Additionally, they suggested that owing to this unnatural healing process, complete healing could take up to 2 years, potentially explaining the longer return-to-play times and the pain and discomfort experienced by athletes receiving these surgical treatments.[15] Fixation using suspensory buttons in cases of proximal tibiofibular joint instability showed less rigid fixation and earlier range of motion compared with screw-only repair.[12] Our goal of using a bicortical tenodesis button with double-row fixation was to achieve the low

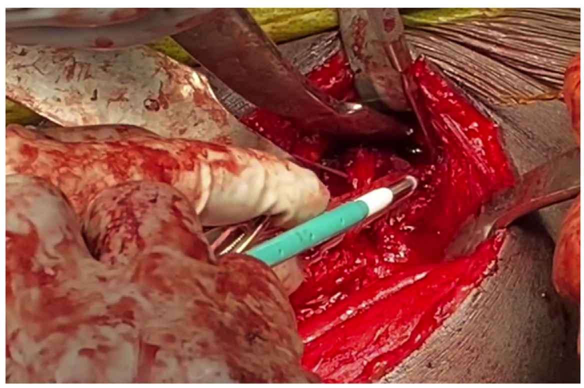

Fig 9. For superior-row placement, a 2.4-mm guide pin is drilled superior to the first anchor and button on the anterior inferior iliac spine. A 4.75-mm tap is then placed, and sutures from the bicortical Tenodesis Titanium Button and sutures from the inferior-row anchor are placed and tensioned in a 4.75-mm Biocomposite SwiveLock anchor. A right hip is shown through the Smith-Petersen approach with the patient in the supine position.

Table 2. Pitfalls and Pearls of Dissection and RF Avulsion Repair Using Bicortical Titanium Tenodesis Button With Double-Row Fixation

Step	Pearl	Pitfall
Performing surgical dissection	Care should be taken to protect the branches of the lateral femoral cutaneous nerve.	The branches of the lateral femoral cutaneous nerve can be transected, causing neurologic anterolateral hip pain.
Drawing out incision	An ultrasound scanner should be used prior to incision to identify retraction of the torn RF tendon to localize the incision and dissection.	Finding the tendon may be difficult if severely retracted.
Incising RF tendon sheath	The surgeon should use sharp dissection and incise the femoral tendon sheath so that it may be repaired while closing.	Failure to create repairable tendon sheath ends will decrease neovascularization of the tendon and repair.
Clearing RF anatomic footprint for tunnel preparation	The inner and outer cortical borders of the AIIS must be visible.	Difficulty may result when assessing the proper angle of the superior aspect of the AIIS for inferior and superior double-row placement.

AIIS, anterior inferior iliac spine; RF, rectus femoris.

recurrence rate seen in surgically managed elite-level athletes. We believe the use of a bicortical tenodesis button with double-row fixation would provide a strong structural repair and address the chronic strain pattern suggested by Sonnery-Cottet et al. and fibrocartilage changes suggested by Newsham-West et al. Continued research is needed to assess the construct strength, early joint mobility, and rigidity of fixation in RF avulsion repair using suspensory devices.

Killian et al.[16] described a concept of controlled loading in rotator cuff tendon repair that could apply to RF avulsion repair, but this has not been specifically described, and future studies should aim to explore controlled loading in RF avulsion repair and postoperative management. This concept of controlled loading influenced our use of a bicortical suspensory button and use of a knee brace limiting knee extension to 30°. The use of bicortical suspensory buttons aims to reduce strain at the enthesis and thus promote a balance of signals conducive to appropriate tendon fibroblast activity to achieve a more natural recovery.

Our postoperative management was influenced by current literature to best manage and accelerate repair with the aim of preventing the postoperative pain and soreness that many athletes report. Additional study will be needed to determine whether this surgical method and postoperative management can be of benefit in any of these categories.

References

1. Rossi F, Dragoni S. Acute avulsion fractures of the pelvis in adolescent competitive athletes: Prevalence, location and sports distribution of 203 cases collected. *Skeletal Radiol* 2001;30:127-131.
2. García VV, Duhrkop DC, Seijas R, Ares O, Cugat R. Surgical treatment of proximal ruptures of the rectus femoris in professional soccer players. *Arch Orthop Trauma Surg* 2012;132:329-333.
3. Sonnery-Cottet B, Barbosa NC, Tuteja S, et al. Surgical management of rectus femoris avulsion among professional soccer players. *Orthop J Sports Med* 2017;5. 2325967116683940.
4. Park CK, Zlomislic V, Du J, Huang BK, Chang EY, Chang DG. Nonoperative management of a severe proximal rectus femoris musculotendinous injury in a recreational athlete: A case report. *PM R* 2018;10:1417-1421.
5. Lempainen L, Kosola J, Pruna R, Puigdellivol J, Ranne J, Orava S. Operative treatment of proximal rectus femoris injuries in professional soccer players: A series of 19 cases. *Orthop J Sports Med* 2018;6. 2325967118798827.
6. Olmo J, Aramberri M, Almaraz C, Nayler J, Requena B. Successful conservative treatment for a subtotal proximal avulsion of the rectus femoris in an elite soccer player. *Phys Ther Sport* 2018;33:62-69.
7. Ueblacker P, Müller-Wohlfahrt H-W, Hinterwimmer S, Imhoff AB, Feucht MJ. Suture anchor repair of proximal rectus femoris avulsions in elite football players. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2590-2594.
8. Gamradt SC, Brophy RH, Barnes R, Warren RF, Thomas Byrd JW, Kelly BT. Nonoperative treatment for proximal avulsion of the rectus femoris in professional American football. *Am J Sports Med* 2009;37:1370-1374.
9. Ouellette H, Thomas BJ, Nelson E, Torriani M. MR imaging of rectus femoris origin injuries. *Skeletal Radiol* 2006;35:665-672.
10. Armfield DR, Kim DH-M, Towers JD, Bradley JP, Robertson DD. Sports-related muscle injury in the lower extremity. *Clin Sports Med* 2006;25:803-842.
11. Hasselman CT, Best TM, Hughes C, Martinez S, Garrett WE. An explanation for various rectus femoris strain injuries using previously undescribed muscle architecture. *Am J Sports Med* 1995;23:493-499.
12. Beck EC, Gowd AK, Nabor D, Waterman BR. Cortical button fixation for proximal tibiofibular instability: A technical report. *Arthrosc Tech* 2020;9:e1415-e1421.
13. Dean CS, Arbeloa-Gutierrez L, Chahla J, Pascual-Garrido C. Proximal rectus femoris avulsion repair. *Arthrosc Tech* 2016;5:e545-e549.

14. Esser S, Jantz D, Hurdle MF, Taylor W. Proximal rectus femoris avulsion: Ultrasonic diagnosis and nonoperative management. *J Athl Train* 2015;50:778-780.
15. Newsham-West R, Nicholson H, Walton M, Milburn P. Long-term morphology of a healing bone-tendon interface: A histological observation in the sheep model. *J Anat* 2007;210:318-327.
16. Killian ML, Cavinatto L, Galatz LM, Thomopoulos S. The role of mechanobiology in tendon healing. *J Shoulder Elbow Surg* 2012;21:228-237.