Technical Note

Surgical Treatment of Chronic Rupture of the Quadriceps Using a Modified Pulvertaft Weave Technique

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Abstract: The extensor mechanism provides active knee joint extension and stability of the patellofemoral joint. Rupture of the quadriceps tendon, although uncommon, is therefore associated with impairment in knee joint stability and, thus, requires surgical repair. Although various techniques provide excellent clinical outcomes for acute rupture, treatment of chronic rupture remains clinically challenging. We describe our modified technique for quadriceps tendon repair using a semitendinosus tendon autograft, with suturing of the quadriceps tendon stump to the patella via transosseous sutures, wherein the use of allograft and anchors is avoided. Our modified Pulvertaft weave technique is simple and reproducible.

The extensor mechanism provides knee extension and stability to the patellofemoral joint. Therefore, structural or functional changes in the quadriceps mechanism, whether congenital or traumatic, such as rupture of the quadriceps tendon, fracture of the patella, or injury to the patellar tendon, disrupt knee joint stability.[1-3] Of these possible injuries, a rupture of the quadriceps tendon is an uncommon but disabling injury that normally results from a strong eccentric contraction of the quadriceps while the knee is in a fixed position of flexion. Atraumatic ruptures may also occur,[4-6] with about 76% of patients who sustain an atraumatic rupture having a systemic disease background, such as diabetes, chronic renal failure, hyperparathyroidism, uremia, or inflammatory arthritis, or a history of chronic use of corticosteroids and fluoroquinolones, as well as repetitive tendinopathy.[7-9]

It is important to note that injuries to the quadriceps tendon are 3 times more common than injuries to the patellar tendon, with the highest prevalence being among patients older than 40 years.[10-12] Various surgical techniques have been developed for the treatment of an acute quadriceps tendon rupture, with transverse bone suture still considered the gold standard, although repair using anchors has been used more widely recently. Overall, outcomes of treatment of acute injuries are generally excellent.[13] In contrast, treatment of chronic quadriceps tendon ruptures to obtain satisfactory clinical outcomes remains challenging.[10,14,15]

Classically used techniques for the repair of chronic (or late) quadriceps rupture, such as the methods described by Scuderi[15] and Codivilla, are technically demanding and difficult to perform in the presence of degenerative changes in the tendon or extensive post-injury tendon retraction.[16-18] Recently, Alaia et al.[19] reported a new technique for quadriceps tendon repair using a semitendinosus tendon allograft, combined with suturing of the quadriceps tendon stump to the patella using anchors. We consider this technique to be an innovative and promising alternative for the treatment of chronic quadriceps tendon ruptures.

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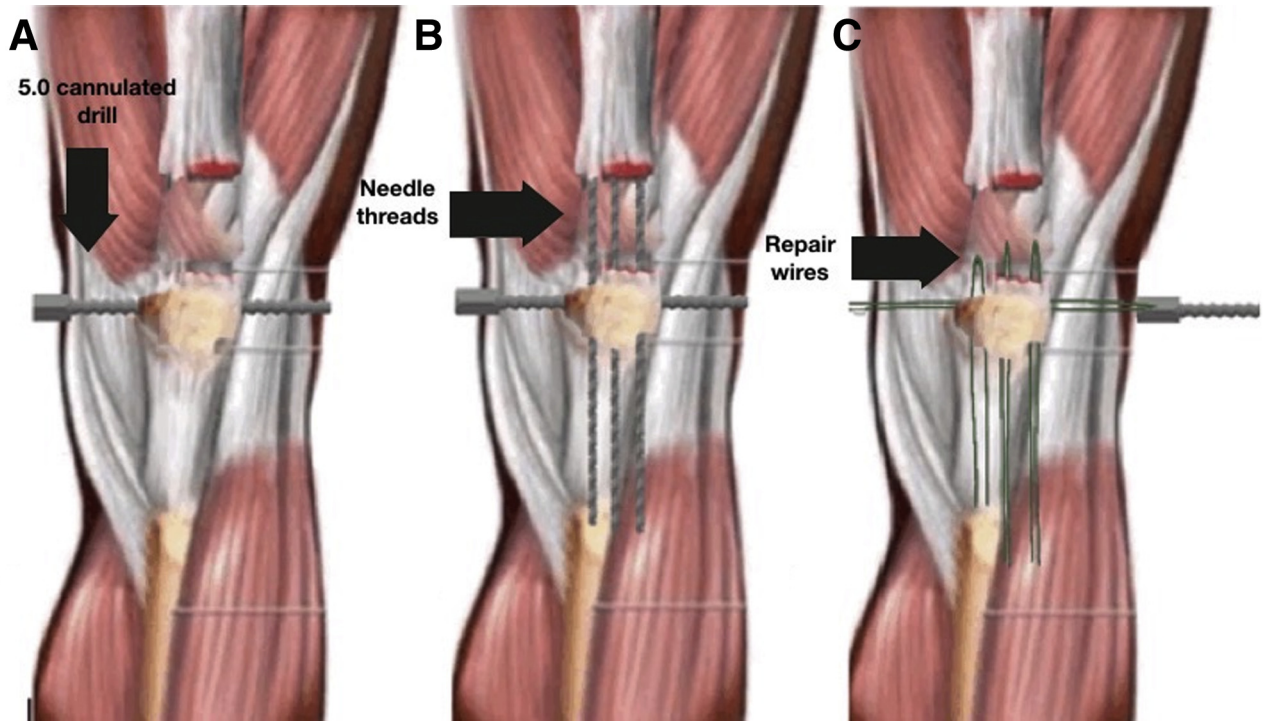

Fig 1. (A) A transverse tunnel is created in the patella using a 5-mm cannulated drill. (B) Three parallel longitudinal tunnels are created for threading. (C) The repair wires are maintained on the carrying handle at the proximal end of each longitudinal tunnel created in the patella to facilitate the transport of the wires.

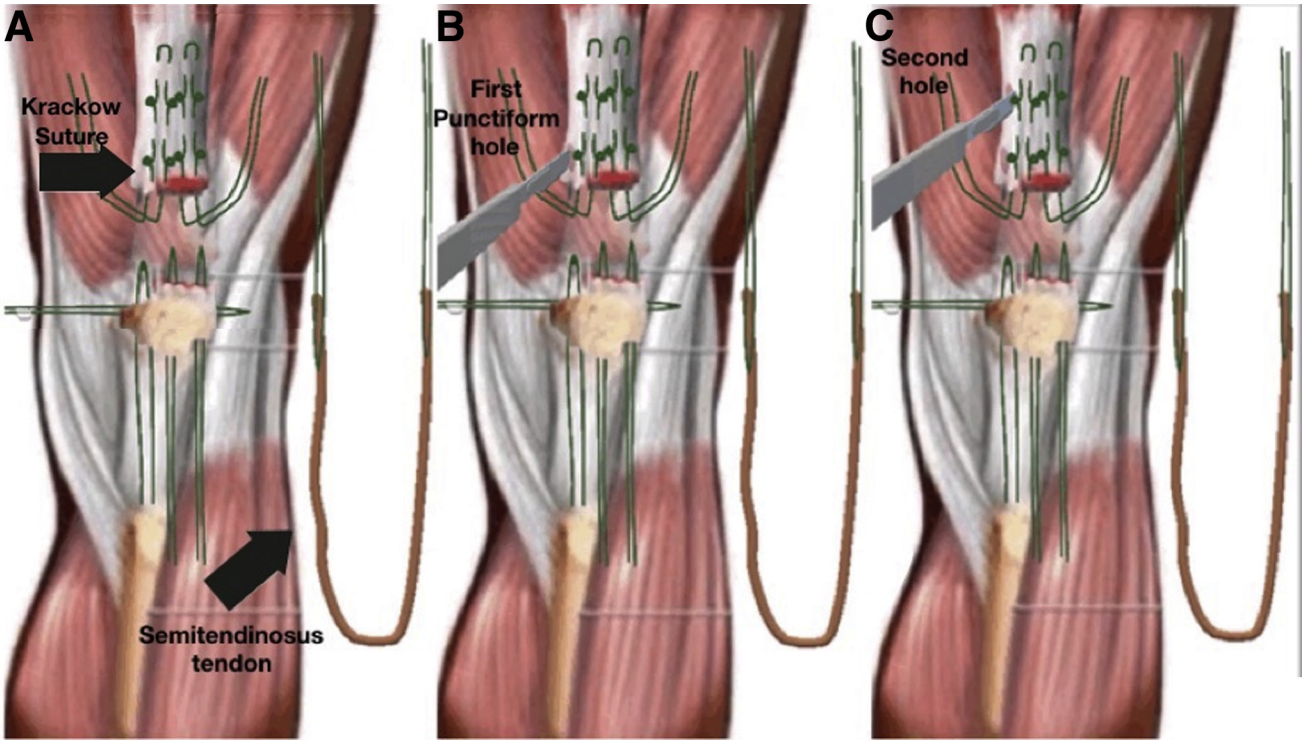

Fig 2. (A) Krackow sutures, using 2 threads of polyester suture (No. 2 Ethibond), are placed in the middle portion of the quadriceps tendon, with 4 wires maintained in situ at the distal end of the quadriceps tendon. The prepared semitendinosus tendon is shown by the arrow. (B) Punctiform holes are created in the medial border of the quadriceps tendon. (C) Punctiform holes are created in the lateral border of the quadriceps tendon. Of note, at least 3 holes should be created in the medial and lateral borders of the quadriceps tendon.

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
Complete placement of the Krackow sutures before weaving the graft in the holes created at the edges of the quadriceps.	Avoid fixation of the semitendinosus graft without considering the traction that needs to be applied to the graft, consequently not reducing the distance between the quadriceps tendon and the proximal pole of the patella.
Keep the 5-mm drill within the patellofemoral joint after creation of the transverse tunnel to allow for the creation of the 3 longitudinal tunnels for threading.	Prevent the Ethibond wires from being drawn into the tunnel before suturing of the distal end of the quadriceps tunnel.
Place multiple sutures on the semitendinosus graft to ensure locking over the extensor mechanism of the knee.	

However, this repair method is limited to hospitals that have easy access to a tissue bank, and it depends on the availability of anchors.[19] Considering these limitations, we set out to improve the technique first proposed by Alaia et al. to avoid the use of an allograft and anchors, thus expanding the indications for this technique. Therefore, our aims in this report were to define our modification of the original technique proposed by Alaia et al. and to provide a complete description of our modified Pulvertaft tendon weaving technique.

Surgical Technique

Patient Positioning and Preparation

The surgical procedure is performed with the patient in the dorsal decubitus position, with a cushion fixed to the surgical table, placed under the middle one-third of the calf to maintain the knee joint in about 45° of flexion. Chlorhexidine detergent is used for aseptic skin preparation, and alcoholic chlorhexidine is used for antiseptic skin preparation. The surgical procedure is

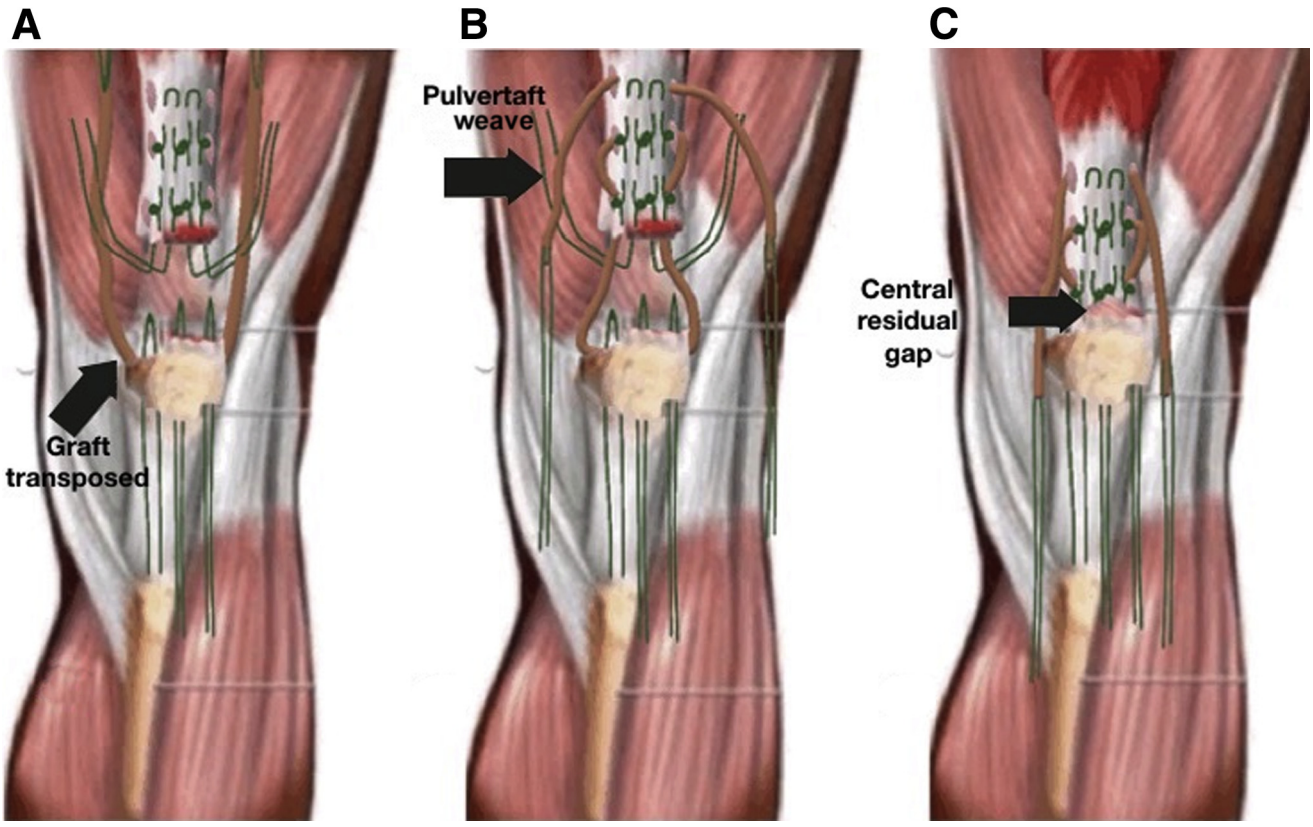

Fig 3. (A) The semitendinosus tendon is passed through the transverse tunnel, leaving 2 symmetrical ends of the graft, shown by the arrow. (B) The 2 ends of the graft are weaved through the medial and lateral holes placed in the borders of the quadriceps tendon, using the Pulvertaft technique, ensuring that, ultimately, the tip of the graft points anteriorly (arrow). (C) The ends of the graft are placed under traction and sutured over the quadriceps tendon to reduce the anterior gap to the extent possible, with only a central gap remaining (arrow).

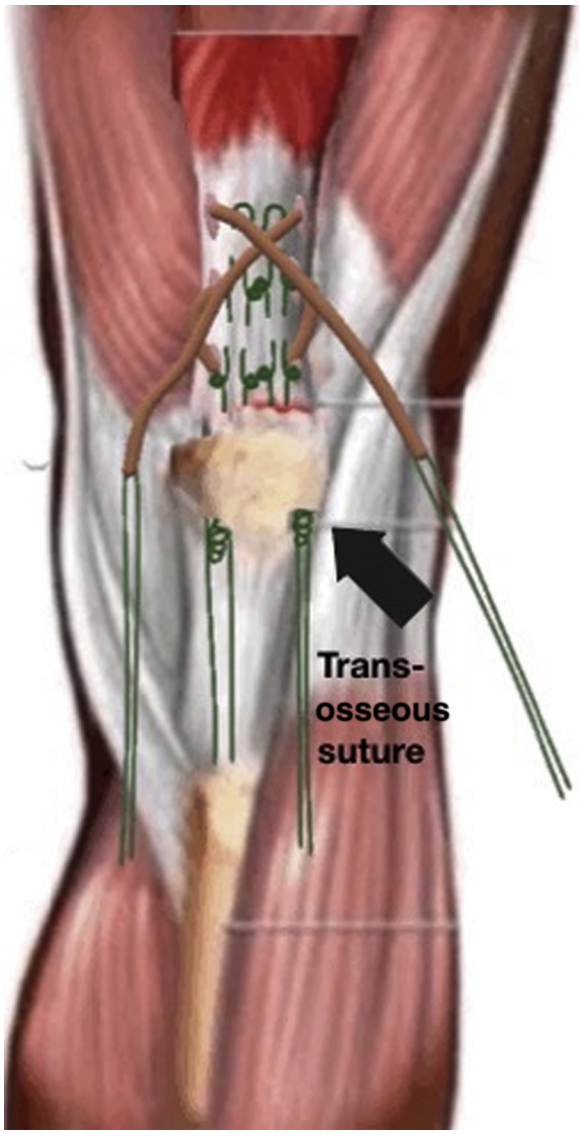

Fig 4. The distal ends of the semitendinosus tendon are placed under traction, crossed over, and sutured over the quadriceps tendon (in a locking X formation) to reduce the anterior gap in the tendon by pulling on the 4 polyester suture strands (from the previous Krackow sutures), forming a transosseous suture in the distal pole of the patella.

performed with the patient under spinal anesthesia and with a femoral nerve block.

Surgical Access

A longitudinal (10-15 cm) incision is made on the anterior-medial surface of the distal thigh, over the area of the quadriceps tendon, for extensive exposure of the patellar tendon, patella, and quadriceps tendon. A second, 4-cm incision is performed to expose the tibial insertion of the medial hamstrings for dissection of the semitendinosus tendon.

Surgical Procedure

Harvesting and preparation of the semitendinosus tendon are first performed, using a standard technique. Subsequently, we proceed with blunt dissection of the proximal stump of the quadriceps tendon, with resection of the fibrotic tissue between the tendon and proximal pole of the patella. A transverse bone tunnel, 5 mm in width, is created at the center of the patella, using a cannulated drill, from medial to lateral (Fig 1A). While a 5-gauge drill is still inside the patella, we create 3 parallel longitudinal tunnels to insert the threading needles (Fig 1B), leaving a repair wire on the carrying handle at the proximal end of each of these 3 tunnels (Fig 1C).

The middle section of the quadriceps tendon is then sutured, using Krackow sutures, with 2 polyester threads (No. 2 Ethibond; Ethicon); the 4 wires at the distal end of the quadriceps tendon are retained (Fig 2A, Table 1). Three to four punctiform holes are created in the medial and lateral borders of the quadriceps tendon (Fig 2B and C) to be used for the threading of the semitendinosus tendon.

The semitendinosus tendon is passed through the transverse tunnel, leaving 2 symmetrical extremities (Fig 3A). Each of these 2 ends is then threaded through the preformed holes in the medial and lateral borders of the quadriceps tendon, per the Pulvertaft technique, ensuring that the tip of the tendon after the final thread is directed anteriorly (Fig 3B). The distal ends of the semitendinosus tendon are then placed under traction, crossed over, and sutured over the quadriceps tendon (in a locking X formation) to reduce the anterior gap in the tendon, with only a residual gap in the central portion of the tendon (Fig 3C). This residual central gap is closed by pulling on the 4 polyester suture strands (from the previous Krackow sutures), forming a transosseous suture in the distal pole of the patella (Fig 4). Preoperative and postoperative radiographs are obtained (Fig 5), and physical examination in full knee extension is performed 3 months after surgery (Fig 6), as shown in a patient in Video 1.

Discussion

Although uncommon, chronic ruptures of the quadriceps tendon are extremely disabling injuries.[20] In our review of the literature on the late treatment of quadriceps tendon ruptures, we identified Technical Notes and case reports describing different techniques and reporting good results.[7,21,22] However, no prospective or case-series studies are available to evaluate treatment effectiveness and clinical outcomes, which reflects the rapid treatment of these injuries in developed countries. In underdeveloped countries, a section of the population typically does not have rapid access to health care for the treatment of

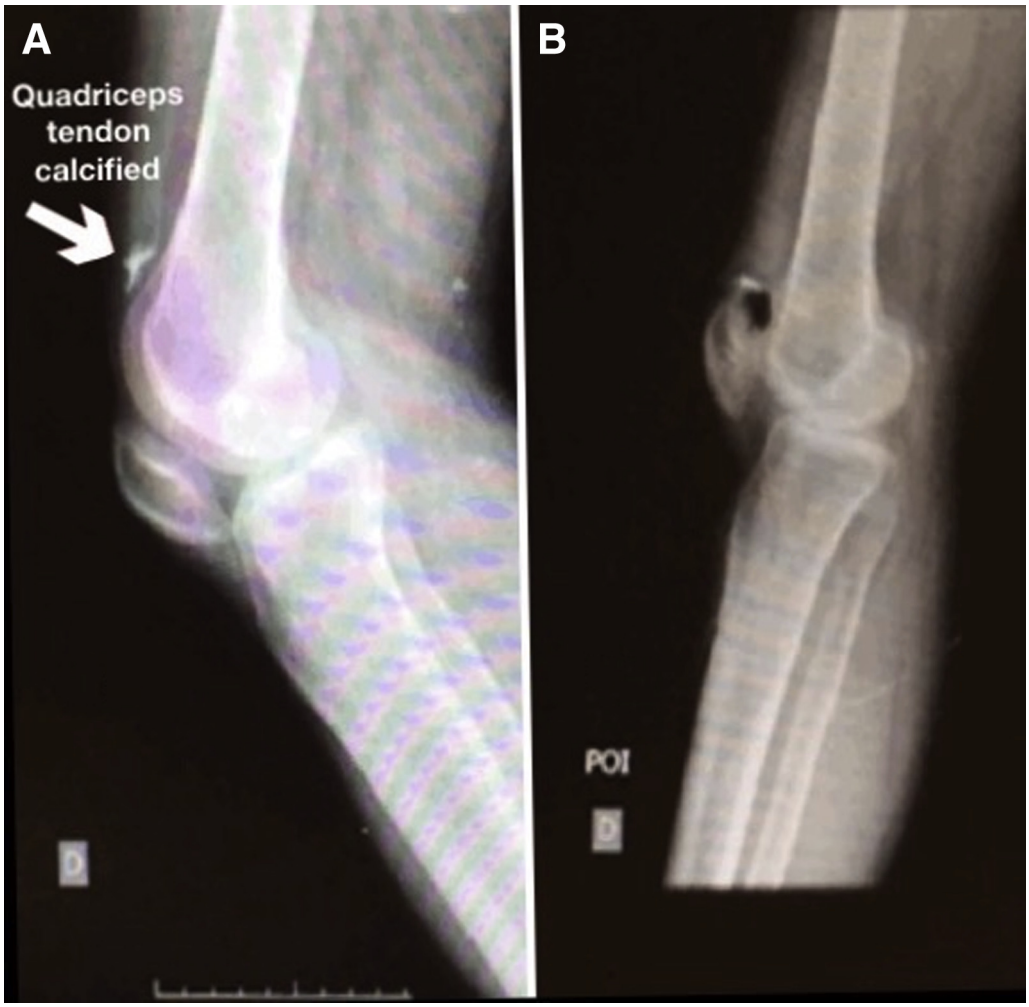

Fig 5. (A) Preoperative radiograph, showing patella baja and calcification of the distal end of the quadriceps tendon (arrow). (B) Immediate postoperative radiograph, showing the distal portion of the quadriceps tendon anchored into the patella.

these injuries, with late repair, therefore, being of clinical importance to improve patient-related outcomes.

A recent review of injuries of the knee extensor mechanism in adults reported worse outcomes of late repair than early repair of a quadriceps tendon rupture, with clinical outcomes being specifically inferior with retraction of the proximal quadriceps.[23] In a systematic review, excellent results were reported for acutely treated patients with a quadriceps tendon rupture. However, because of the rarity of late (chronic) repair of quadriceps tendon ruptures, defined by a surgical repair more than 3 weeks after injury, a reliable assessment of clinical outcomes is not available. It is important to note that none of the 12 studies included in this meta-analysis evaluated the Pulvertaft tendon weaving method.[20] In fact, in their review, Pengas et al.[23] identified various techniques for the late treatment of quadriceps tendon ruptures, including the traditional Codivilla technique[16]; the use of hamstring tendon autograft, synthetic materials, and autologous hamstring tendon graft; and the use of a synthetic Prolene ribbon (Ethicon) (with platelet-rich plasma).[24,25]

Regarding fixation, a 2017 meta-analysis did not report a statistical difference between anchor fixation and transosseous sutures.[26] Regarding clinical outcomes, among patients treated with transosseous sutures, West et al.[27] reported an increase in active knee

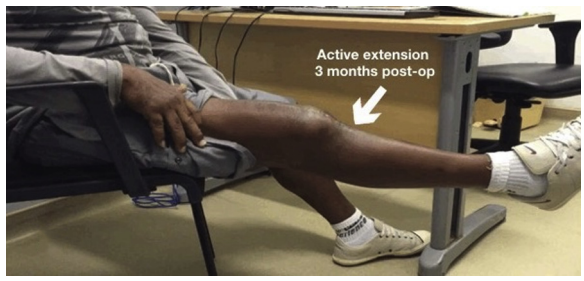

Fig 6. Physical examination showing full active knee extension achieved at 3 months postoperatively (post-op).

Table 2. Advantages and Disadvantages

	Advantages	Disadvantages
Pulvertaft tendon weaving technique	Allows the use of this technique for ruptures with large retraction of the quadriceps tendon, as well as cases of re-ruptures of the quadriceps	Technically more demanding
Transosseous suture	Does not require the use of anchors	Risk of patellar fracture
Semitendinosus autograft	Allows biological integration of the tendon graft	Risk of rupture of the semitendinosus tendon in patients with inferior quality of tendons, such as those with chronic renal failure

extension from 0° to 120° after repair of quadriceps tendon ruptures, with an associated increase in the Lysholm score, in 80% of patients; however, a persistent knee extension lag of 3° to 10° was identified in 20% of cases. Similarly, Konrath et al.[14] reported an increase in active knee extension range from 2° to 125° after repair using transosseous sutures, with an increase in function (as measured by the Lysholm score). However, Serino et al.[26] reported a higher rate of complications being associated with early postoperative mobilization (<6 weeks after surgery) than after a period of postoperative immobilization of 6 to 8 weeks.

On the basis of our findings, we propose that our modified Pulvertaft weave technique provides a viable alternative to conventional late repair of quadriceps tendon ruptures, which does not require the use of allografts and anchors. Our approach could be of specific value in countries with developing economies, such as Brazil, where access to health care and allografts may not be readily available (Table 2). We also believe that the use of autologous tendon grafts can provide additional biomechanical benefits compared with allografts. Surgical treatment of chronic (late) ruptures of the quadriceps tendon using our modified Pulvertaft tendon weaving technique, with the semitendinosus tendon used as an allograft, is reproducible and provides clinical results deemed excellent.

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