Review Article

Quadriceps tendon ruptures: a narrative review

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Background and Objective: Quadriceps tendon ruptures can occur in both the native knee and in knees which have undergone prior total knee arthroplasty (TKA). Complete ruptures require surgical treatment to optimize patient function. Debate exists surrounding the ideal repair technique for native ruptures, and there is little consensus regarding the optimal surgical treatment option for post-TKA ruptures. The objective of this narrative review is to provide an overview of quadriceps tendon ruptures occurring in both native knees and in the setting of TKA, with a focus on contemporary treatment options and their results.

Methods: A narrative review of the relevant literature was performed in November 2024. English language articles published up to November 2024 which related to quadriceps tendon ruptures, involving both the native knee and the post-TKA knee, were reviewed. All types of published articles were considered.

Key Content and Findings: Quadriceps tendon ruptures almost always occur in patients with antecedent tendon pathology. Primary repair of acute native quadriceps ruptures is supported by a large body of literature, and most patients have reasonable outcomes. The clinical outcomes of transosseous and suture anchor repair techniques seem to be comparable in this setting. Quadriceps ruptures, which occur in the setting of TKA, are much more difficult to treat. In this setting, the complication rates of primary repair, repair with augmentation, and reconstruction are high. Even with improvements in the contemporary reconstructive options, including allograft and synthetic mesh, outcomes remain suboptimal. More work is needed to improve outcomes for patients with post-TKA quadriceps tendon ruptures.

Conclusions: Generally reliable results can be achieved when treating native quadriceps tendon ruptures with contemporary techniques. Quadriceps ruptures, which occur in the setting of TKA, on the other hand, are much more challenging to treat. Various surgical techniques have been explored and developed in an effort to improve outcomes. While modest improvements have been realized, these injuries remain problematic, with very high complication and failure rates, regardless of technique.

Keywords: Quadriceps tendon rupture; total knee arthroplasty (TKA); extensor mechanism disruption; extensor mechanism reconstruction; quadriceps repair

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Introduction

Background

Quadriceps tendon ruptures are potentially disabling injuries which often require surgical treatment and may result in long-term functional impairment (1). Physicians may encounter these injuries in both native knees and in those which have undergone prior total knee arthroplasty (TKA), both of which can be challenging to treat and rehabilitate. Patients who sustain these injuries often have preexisting medical comorbidities, specifically those associated with tendinopathy (2,3). Primary surgical repair of acute quadriceps ruptures occurring in the native knee is supported by a large body of biomechanical and clinical data (4), with most contemporary debate focused on the repair technique (i.e., transosseous versus suture anchor repair). Quadriceps ruptures occurring after TKA, on the other hand, are often more difficult to manage and result in greater complications and inferior clinical outcomes (5). The results of primary surgical repair of quadriceps rupture after TKA have been poor (6), which has led to the development of several different reconstructive techniques, including the use of allograft, autograft, synthetic material, and local flaps.

Rationale and knowledge gap

In the treatment of native quadriceps tendon ruptures, there remains some debate among surgeons regarding which repair technique is optimal. In the treatment of post-TKA quadriceps tendon ruptures, clinical results have not been nearly as good as those after treatment of native ruptures, which has led surgeons to explore several different repair and reconstructive techniques in an effort to improve outcomes. Despite improvements in techniques and reconstruction options, results have been inconsistent, and no consensus exists regarding the optimal treatment strategy.

Objective

The objective of this narrative review is to provide an overview of the published literature relating to quadriceps tendon ruptures occurring in both the native knee and after TKA, with a focus on contemporary treatment options and their published results. Specific attention was given to risk factors (both patient-related and surgical), comparisons of repair techniques for native ruptures, and outcomes of the various techniques which have been utilized for treatment of post-TKA ruptures. We present this article in accordance with the Narrative Review reporting checklist (available at https://aoj.amegroups.com/article/view/10.21037/aoj-24-66/rc).

Methods

A narrative review of the relevant literature was performed in November 2024. The search was performed using Google Scholar and PubMed databases, including English language articles published up to November 2024. All types of published articles were considered, including both clinical and non-clinical investigations. Studies were selected based on a review of the title and abstract to determine the study's relevance to the topic. Studies concerning quadriceps tendon ruptures in native knees, quadriceps tendon ruptures after TKA, and anatomic/biomechanical studies relating to quadriceps tendon ruptures and/or repairs/reconstructions were considered. All studies were cross-referenced to find additional resources, and final consideration was given after a review of the full article. A summary of research strategies used for this article can be found in *Table 1*.

Incidence and risk factors

Native quadriceps ruptures

Quadriceps tendon ruptures in the native knee are relatively rare and have been reported to occur with an incidence of approximately 1.37 per 100,000 per year (7). The normal, healthy quadriceps tendon is a very strong structure which can withstand large loads without rupture (8,9). Experimental data suggest that approximately 75% of the quadriceps tendon's fibers must be disrupted before normal physiologic stresses can cause the tendon to rupture (9). Even when subjected to extremely high loads, approximately 50% of the tendon's fibers must be disrupted before a rupture can occur (9), suggesting that rupture of the quadriceps tendon requires a weakened/pathologic tendon. Histopathological data support this theory, as biopsy specimens of spontaneously ruptured quadriceps tendons demonstrate pathologic changes and absence of a healthy structure in all cases (10). This may explain why patients who sustain quadriceps ruptures often have underlying medical comorbidities, specifically those which are associated with tendinopathy (11), including diabetes, thyroid disease, systemic inflammatory disorders, renal disease, and dyslipidemia. Males and older patients are

Table 1 Narrative review search strategy summary

Items	Specification
Date of search	November 1, 2024
Databases and other sources searched	PubMed, Google Scholar
Search terms used	(quadriceps tendon rupture) OR (quadriceps tendon repair) OR (quadriceps tendon reconstruction) OR (quadriceps tendon knee arthroplasty) OR (quadriceps tendon knee replacement)
Timeframe	Up to November 2024
Inclusion and exclusion criteria	Inclusion: English language, full text peer-reviewed articles
	Exclusion: articles involving animal subjects, articles written in non-English language
Selection process	Article selection was performed by analyzing the article's title and abstract for relevance to the topic by two coauthors (J.A.W. and P.L.)

also at higher risk (11), and this is likely related to a higher incidence of tendinopathy with increasing age and male sex.

Several factors have been implicated as a cause for tendinopathy in these patients, including accelerated mucoid degeneration and tendolipomatosis, disorganized collagen and extracellular matrix architecture, and abnormalities in the normal repair response, among others (12). While the exact causes are uncertain, there is likely a complex interplay of factors which ultimately result in abnormal tendon metabolism and homeostasis, which affects the tendon's normal repair and remodeling response and its ability to resist mechanical forces. Regardless of the pathologic mechanism, it appears that the central factor present in all patients who sustain these injuries is disordered tendon homeostasis.

Quadriceps ruptures after TKA

Although few studies have reported on the contemporary incidence of quadriceps tendon rupture after TKA, it has been reported to occur in approximately 0.1% to 1.1% of patients undergoing primary TKA (5,6,13). Like quadriceps ruptures occurring in the native knee, abnormal tendon homeostasis is likely a prerequisite (and the main contributing factor) for these injuries. However, the causes for pathologic tendon physiology in these patients may be related not just to patient factors but also to surgical factors from the TKA procedure.

Patient-related risk factors for quadriceps tendon ruptures after TKA are similar to those for native ruptures. Lin *et al.* recently performed a large-scale database study of >120,000 patients undergoing TKA, including 517 patients with postoperative quadriceps tendon ruptures (0.41% incidence), in order to identify potential patient-related and medical risk factors for this complication (14). The authors found that increased Charlson Comorbidity Index (CCI), obesity, and fluoroquinolone use at any time after TKA were significantly associated with quadriceps tendon rupture (14). In addition, no statistically significant association with the development of a quadriceps tendon disruption was found for advanced age, sex, tobacco use, and chronic corticosteroid use (14).

There are also several surgical factors which have been postulated to contribute to postoperative quadriceps rupture after TKA. Like the patient-related risk factors, many of these factors are likely related to disruptions to the normal tendon homeostasis. Investigations of postoperative changes to the quadriceps tendon after TKA have demonstrated a high incidence of pathologic changes. In an ultrasound-based investigation of quadriceps tendon changes after TKA, nearly 90% of tendons demonstrated pathologic changes, compared with just 4% of non-operated, contralateral tendons (15). The operative tendons also demonstrated significantly increased neovascularization and reduced stiffness compared to the non-operated, contralateral side (15). While these changes partially recovered with time, significant changes were detectable even after 2 years postoperatively, with 80% of quadriceps tendons demonstrating pathologic changes greater than 2 years after TKA (15). It is likely that the pathologic changes occurring after TKA predispose patients to quadriceps ruptures. Prior surgeries to the knee are a well-documented risk factor for quadriceps disruption after TKA (6), and this may be related to pathologic postsurgical changes, which weaken the tendon and increase risk of rupture. Compromise to the vascular supply of the

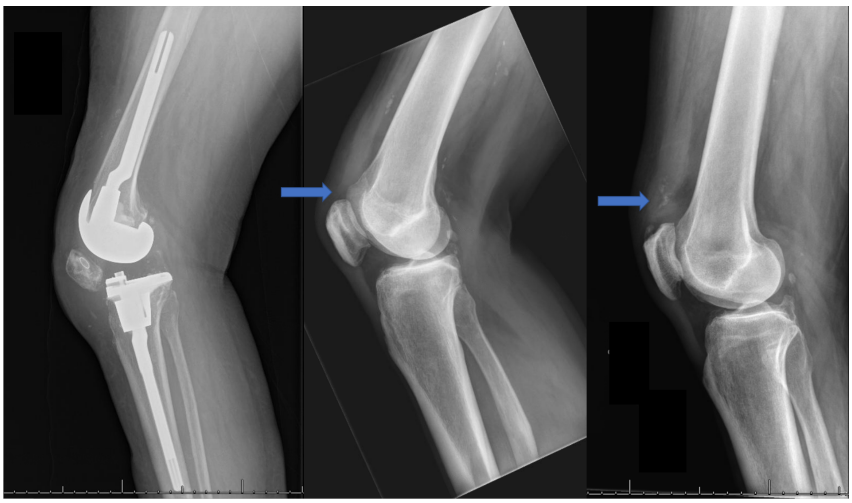

Figure 1 Lateral plain radiographs demonstrating: patella baja in a patient with a quadriceps rupture after total knee arthroplasty (left); disruption of the quadriceps tendon shadow (indicated by the blue arrow) in a patient with a native quadriceps rupture (middle); spurs and calcifications in the bone-tendon junction (indicated by the blue arrow) indicating antecedent tendinopathy (right).

quadriceps tendon related to the surgical approach may contribute, as geniculate arteries supplying portions of the quadriceps tendon may be disrupted with a medial parapatellar arthrotomy (16,17). A lateral retinacular release performed at the time of TKA may further compromise the tendon's blood supply and increase the risk of postoperative quadriceps rupture (16). Other surgical factors which may increase the risk of quadriceps rupture after TKA include prosthetic malposition or malalignment, rotational instability, changes to the joint line, and iatrogenic injury (18). Finally, a history of prosthetic joint infection (PJI) is a major risk factor for quadriceps disruption after TKA, and is associated with substantial morbidity (19).

Diagnosis

Physical examination is often adequate to diagnose a complete disruption of the quadriceps tendon in both native and post-TKA knees when patients present with an extensor lag and/or a palpable defect over the tendon. If the diagnosis is uncertain, imaging studies may provide additional information and guide the appropriate diagnosis. Radiographs may demonstrate patella baja, a disruption of the quadriceps tendon shadow, and/or avulsion of small fragments from the patella (*Figure 1*). Spurs and calcifications in the bone-tendon junction, indicating antecedent tendinopathy, are often seen (*Figure 1*). Magnetic resonance imaging (MRI) may be used to confirm the diagnosis (*Figures 2,3*).

Treatment and outcomes

Complete ruptures of the quadriceps tendon in both the native and post-TKA knee require surgical treatment to optimize function.

Native quadriceps ruptures

Acute ruptures of the native quadriceps tendon are generally treated with prompt surgical intervention, as delays in treatment are associated with retraction and atrophy of the quadriceps muscle and decreased functional outcomes (20). Primary repair in this setting has a high rate of success. Ciriello et. al performed a systematic review of studies evaluating clinical outcomes after repair of native quadriceps ruptures and found that the majority of studies reported good or excellent range of motion and return to pre-injury activity levels, although most patients also had some degree of quadriceps muscle atrophy and a strength deficit (21). Complications which were reported included heterotopic ossification (6.9% of patients), venous thromboembolism (2.5%), superficial infection (1.2%), and deep infection (1.1%), and an overall rate of re-rupture of 2% (21).

The most common techniques for primary repair include transosseous suture repair, which utilizes sutures passed through longitudinal drill holes in the patella, and suture

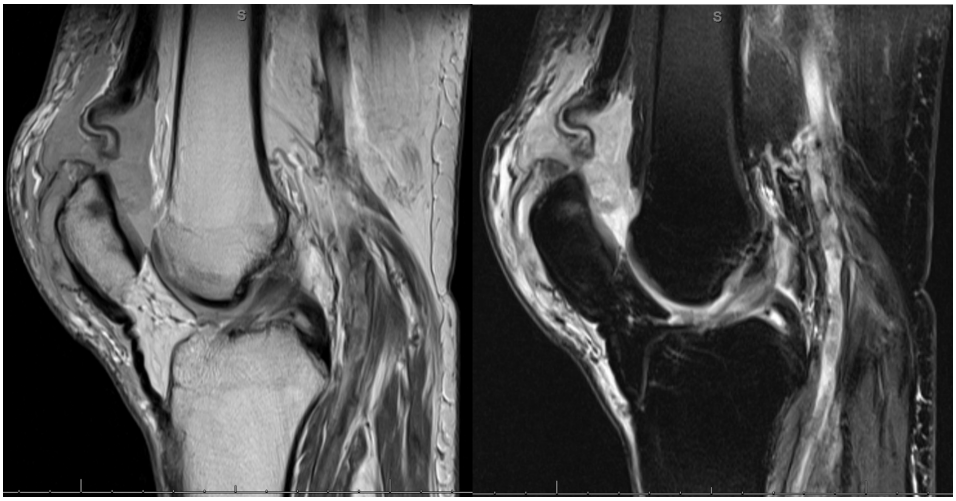

Figure 2 Sagittal MRI sequences demonstrating a quadriceps tendon rupture in a native knee. MRI, magnetic resonance imaging.

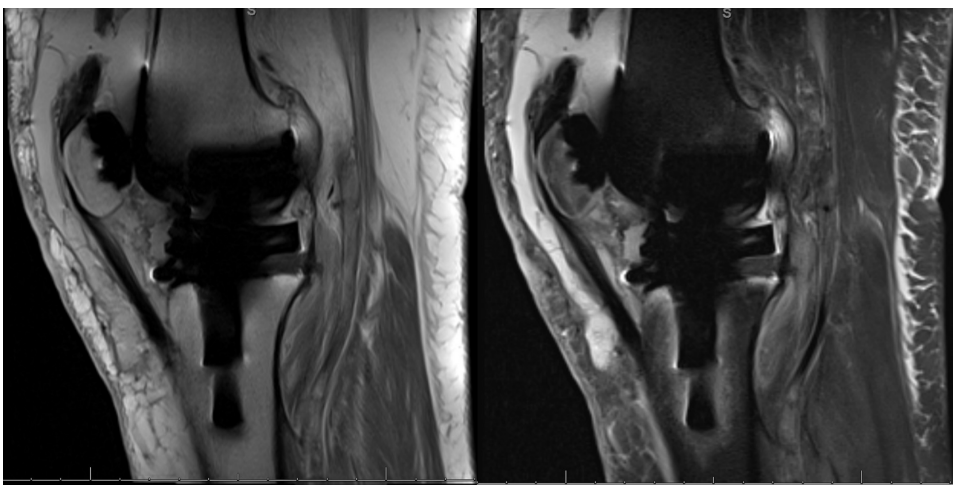

Figure 3 Sagittal MRI sequences demonstrating a quadriceps tendon rupture occurring in the setting of a total knee arthroplasty. MRI, magnetic resonance imaging.

anchor repair, which utilizes suture anchors secured to the proximal pole of the patella. Proposed advantages of suture anchor repair include the ability to make a smaller incision, which may reduce the rate of infection and wound complications. On the other hand, suture anchors require larger drill holes in the patella, which may increase risk of patellar fracture, and have a higher cost (22). Clinical and biomechanical data comparing the two techniques have been mixed (4). Coladonato *et al.* recently performed a systematic review and meta-analysis evaluating the clinical and biomechanical outcomes of the two repair constructs in order to elucidate any possible differences (4). The investigation included 24 studies (18 clinical, 6 biomechanical). The authors found no significant difference in clinical outcomes, which included patient-reported outcome metrics (Lysholm Knee Scoring Scale), repair failure/re-rupture, and postoperative knee range of motion (4). Biomechanical outcomes, which included mean load to failure, were also found to be similar between transosseous and suture anchor repair constructs (4). The authors noted, however, that the strength of these conclusions is limited as most clinical studies in the published literature represent level IV evidence. Based on the currently available body of literature, it appears that results are generally equivalent between the two techniques,

and surgeons can choose whichever technique is most reliable in his/her hands.

Chronic native quadriceps tendon ruptures, defined as those which are diagnosed or treated at three weeks or more from the time of injury, are challenging to treat and are associated with poor functional outcomes. Because most quadriceps ruptures are treated with prompt surgical repair, chronic ruptures are relatively rare in developed countries. As a result, there are few studies evaluating treatment techniques and no gold-standard surgical option exists for chronic native quadriceps ruptures. Chronic ruptures are often associated with large defects and/or fibrotic retraction of the tendon which limits the ability to successfully perform primary repair. Many different reconstructive options have been described, including local rotation flaps, various autografts (e.g., hamstring, peroneal, sartorius tendon autografts), and different types of allograft and synthetic materials (23). Pintore *et al.* recently published a novel technique in which the quadriceps tendon was reconstructed using a transfer of the ipsilateral sartorius muscle (23). In this study, 19 patients with chronic quadriceps tendon ruptures (mean of 115 days from the time of injury to surgery) were treated with a transfer of the ipsilateral sartorius muscle-tendon unit by detaching the tendon from its distal insertion on the tibia, mobilizing the muscle-tendon unit anteriorly, and attaching the muscle-tendon unit to the proximal patella and surrounding quadriceps muscle. The authors reported satisfactory clinical outcomes, including a mean Knee Society Score (KSS) of 90.9 with minimal extensor lag (mean 3.8 degrees), at mean follow-up of 4.4 years postoperatively using this technique. Overall, the body of literature describing the treatment of chronic native quadriceps ruptures is scarce and is generally limited to small series and case reports, and more data is needed to optimize outcomes for patients who present with this challenging problem.

Quadriceps ruptures after TKA

Quadriceps ruptures occurring after TKA are often more difficult to manage and result in greater complications and inferior clinical outcomes (5). Furthermore, there is little consensus regarding the optimal surgical treatment options. Unlike with the treatment of native quadriceps ruptures, the results of primary repair of post-TKA quadriceps ruptures have been poor. More recently, surgeons have tried direct primary repair with augmentation techniques (e.g., with allograft, autograft, and/or synthetic mesh) in an attempt to improve outcomes. The results of primary repair of post-TKA quadriceps tendon ruptures, with or without augmentation, are shown in *Table 2*. While outcomes are generally suboptimal, the results suggest that a subset of patients, specifically those who sustain acute ruptures and undergo surgical repair in a timely fashion, seem to have better outcomes than those with older injuries or those who undergo delayed surgical repair.

Given the suboptimal results of primary repair, several different reconstruction techniques have been developed, including the use of allograft, autograft, synthetic material, and local flaps. The most commonly used reconstructive techniques include allograft reconstruction and reconstruction with synthetic mesh. Allograft reconstruction is most commonly performed using one of two techniques: Achilles tendon allograft (including Achilles tendon with calcaneal bone block) or whole extensor mechanism allograft (including quadriceps tendon, patella, and patella tendon with tibial bone block) (*Figure 4*). A whole extensor mechanism allograft may be required in the setting of a deficient patella or if the patella cannot be mobilized to within three to four centimeters of the joint line (6). Achilles tendon allograft can be used when the patella and patellar component are intact and when the patella can be mobilized to within three to four centimeters of the joint line (6). Additionally, given its increased length, Achilles tendon allograft can be useful for chronic quadriceps ruptures with proximal retraction (6). Reconstruction with synthetic mesh was developed because of the highly variable outcomes with allograft techniques. The use of a specific monofilament polypropylene mesh has been reported most in the published literature (29), but an alternative polyester mesh has also been described (2). Prior to any extensor mechanism reconstruction, a thorough history, physical examination, and review of imaging studies is critical to detect signs and symptoms suggestive of instability, patellar maltracking, or component malpositioning. These are all potential contributing factors in the etiology of post-TKA extensor mechanism disruption, and if present, must be addressed concurrently in order for any extensor mechanism repair or reconstruction to be successful. The surgeon should be prepared to revise tibial or femoral components at the time of extensor mechanism repair or reconstruction, and several case series have reported the need for simultaneous component revision in a large percentage of patients (up to 80%) undergoing post-TKA extensor mechanism reconstruction (19,30,31).

Vajapey *et al.* recently performed a systematic review

Table 2 Study characteristics for contemporary studies reporting on post-TKA quadriceps repair, with or without augmentation

Author (year)	No. of cases included	Additional injury details, if provided	Treatment	Follow-up duration (months), mean	Outcome
Dobbs *et al.*, 2005 (5)	10	Mean interval from TKA to rupture: 32 months	Three early repair, five late repair, two late repair with augmentation	34	Six with an unsatisfactory result (60%), including four re-ruptures (40%)
Vaishya *et al.*, 2016 (24)	2	Acute ruptures	Direct repair	8.5	Mean 10-degree extensor lag
Nodzo and Rachala, 2016 (3)	7	Mean time from rupture to repair: three months	Repair with synthetic mesh augmentation	34	Clinical success (defined as extensor lag <30-degrees) in four cases (57%)
Ormaza *et al.*, 2017 (25)	3	Chronic partial tears	Suture repair with synthetic mesh augmentation	19	"Clinical success" in all three cases
Soong *et al.*, 2017 (26)	4	Mean interval from TKA to rupture: 0.75 months	Direct repair	9.5	Three patients (75%) with poor functional outcome scores
Chhapan *et al.*, 2018 (13)	10	Three partial ruptures, seven complete ruptures; mean interval from TKA to rupture: 33 days	Direct early repair (mean interval from rupture to repair: 2 days)	12	All patients with good functional outcomes; no cases of re-rupture or significant extensor lag
Courtney *et al.*, 2018 (27)	27	15 acute (<2 weeks) ruptures, 12 non-acute ruptures	Direct repair	82	Four reoperations (15%), 6 patients with a poor outcome (22%)
Neitzke *et al.*, 2024 (28)	15		13 direct repair, two repair with augmentation (one autograft augmentation, one allograft augmentation)	36	Three re-ruptures (20%)

TKA, total knee arthroplasty.

evaluating the results of the different reconstructive techniques for post-TKA extensor mechanism disruptions (32). The authors noted an overall complication rate of ~26% after quadriceps tendon reconstruction, which was similar to the overall complication rate of repair (~25%) (32). Interestingly, the overall complication rate after treatment of early extensor mechanism ruptures (defined as extensor mechanism disruptions occurring within 3 months of TKA) was found to be higher (~34%) than the complication rate after treatment of late injuries (~23%) (32). Common complications occurring after treatment of early ruptures included infection and poor functional outcomes, while infection and re-rupture were common complications after treatment of late injuries (32). Overall, the most common complication after repair and reconstruction of the extensor mechanism was an extension lag of 30 degrees or greater, which constituted ~45% of all complications (32). Re-rupture and infection both accounted for approximately one fourth of all complications (~25% and ~23%, respectively) (32). Overall, the authors noted a high complication rate, but the quality of the available evidence did not permit a robust statistical analysis to compare the different types of reconstructive options. More high-quality research is needed in this area to guide the optimal treatment (whether repair or reconstruction, and which technique) for quadriceps tendon ruptures occurring in the setting of prior TKA.

Deren *et al.* performed a recent meta-analysis aiming to compare the results of allograft and synthetic mesh reconstruction techniques for any type of extensor mechanism disruption after TKA, which also included patella/patellar tendon disruptions (33). Thirty studies were included in the analysis. The authors noted an overall success rate of 73.3%, with no difference in the success rate of allograft reconstruction (72.8%) versus synthetic mesh reconstruction (78%). Furthermore, there were no differences in revision rates (allograft: 14.2%; synthetic

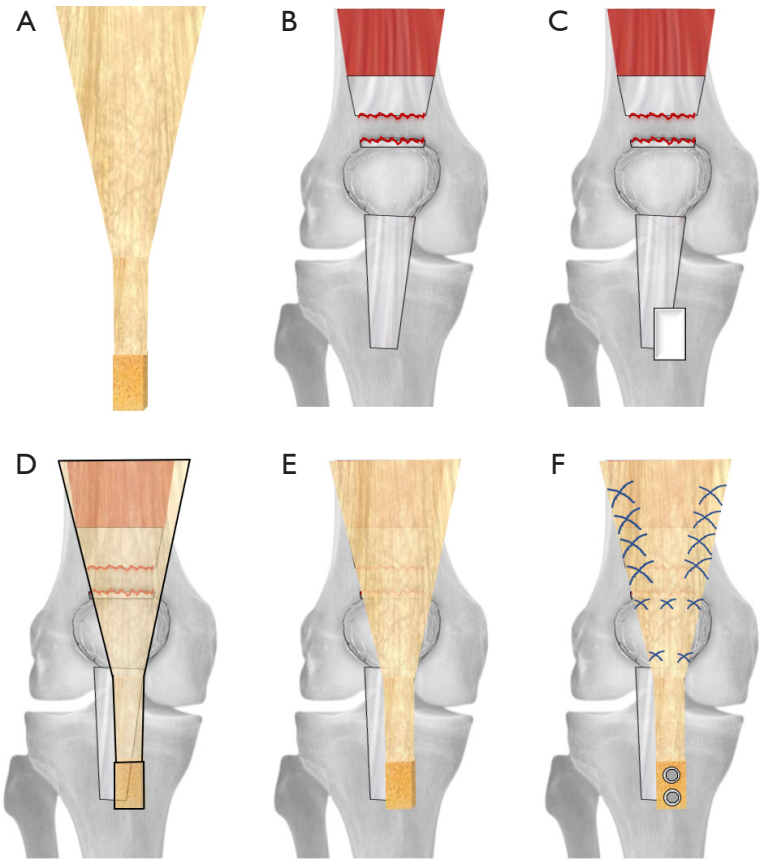

Figure 4 Illustration of Achilles tendon allograft reconstruction of a quadriceps tendon rupture. (A) Achilles tendon allograft with calcaneal bone block. (B) Illustration of a knee with a quadriceps tendon rupture. (C) After creation of a trough in the host proximal tibia to accept the allograft bone block. (D,E) Illustration of Achilles allograft placement on the native knee [allograft tissue transparent and outlined in (D) to illustrate placement]. (F) After fixation of the allograft bone block and after the allograft tendon has been secured to the native tendon and patellar retinaculum.

mesh: 16%) or relative risk of infection between allograft and synthetic materials. Finally, there was no significant difference in mean postoperative KSS between the groups (allograft: 73.1; synthetic mesh: 72.7). The authors concluded that the current literature suggests that allograft and synthetic mesh extensor mechanism reconstruction after TKA offer similar results with regard to overall failure and revision rates, infection, and functional outcomes, although the risk for failure and infection is significant regardless of the material/technique used. It should be noted, however, that this investigation included all types of extensor mechanism disruptions after TKA and was not limited to quadriceps tendon ruptures. As mentioned above, the body of published literature describing the results of post-TKA quadriceps tendon reconstruction is scarce, and more data is needed in order to better understand how the different types of reconstructive materials (i.e., autograft, allograft, synthetic mesh) perform in this setting.

There may be some patients for which extensor mechanism allograft or synthetic reconstruction may not be feasible, such as those with poor skin coverage, contracted and devascularized skin flaps, previous infection, and/or deficient patellar bone stock. In these settings, gastrocnemius rotational flaps have been used to salvage limb function. This technique involves harvesting the distal tendinous portion of the medial (or lateral) gastrocnemius along with the muscle belly and retracting the muscle-tendon unit proximally over the anteromedial aspect of the knee, with attachment to the remaining extensor mechanism (34). Benefits of this technique include the ability to provide soft tissue coverage in the setting of infection or wound necrosis, improved vascularity provided by the muscle, and a lack of dependence

on patellar bone stock, which is required for some alternate reconstructive techniques (6). While published studies of this technique are rare, reported results have been modest, with many patients experiencing positive outcomes and regaining the ability to ambulate independently (34-36). This technique may be useful as an alternative to allograft/synthetic reconstruction in patients with poor soft tissue coverage, infection, etc., but may also be a promising option for revision extensor mechanism reconstruction, which is discussed in the next section.

Post-TKA revision extensor mechanism reconstruction

Re-rupture is a common complication after repair or reconstruction of post-TKA extensor mechanism disruptions, and few reliable treatment options exist after failed reconstruction. Bracing can be considered for poor surgical candidates, while patients with concurrent PJI are often treated with arthrodesis, both of which have poor outcomes (37). Revision extensor mechanism reconstruction can be considered in these situations. Published outcomes after revision of extensor mechanism reconstruction, however, are scarce. The authors are aware of two studies in the published literature that have evaluated the outcomes of revision extensor mechanism reconstruction after TKA. Lewullis *et al.* analyzed eight patients undergoing revision extensor mechanism allograft reconstruction after failure of previous allograft reconstruction and noted a failure rate (defined as presence of PJI or extensor lag >20 degrees) of 75% (38). A more recent study included 10 patients who underwent whole extensor mechanism reconstruction (for both the index and the revision reconstruction), seven of whom (70%) experienced extensor mechanism failure at a mean of 33 months (37). More research is needed in this area to optimize the treatment of patients requiring revision extensor mechanism reconstruction.

Conclusions

Pathologic changes to the quadriceps tendon appear to be a prerequisite for a quadriceps tendon rupture, and the treating physician should suspect the presence of a systemic medical condition in any patient presenting with this injury. In general, reliable results can be achieved when treating native quadriceps tendon ruptures with contemporary primary repair techniques, and most patients return to their baseline levels of activity, although strength deficits are common. Quadriceps ruptures, which occur in the setting of TKA, on the other hand, are much more challenging to treat. Various surgical techniques have been explored and developed in an effort to improve outcomes. While modest improvements have been realized, these injuries remain problematic, with very high complication and failure rates, regardless of technique.

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Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://aoj.amegroups.com/article/view/10.21037/aoj-24-66/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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