

# Association of Quadriceps Tendon Harvest for ACL Reconstruction With Development of Osteochondritis Dissecans of the Patella in Pediatric Patients

Sofia Hidalgo Perea,<sup>\*†</sup> BS, Danielle E. Chipman,<sup>\*</sup> BS, Frank A. Cordasco,<sup>§</sup> MD, MS, Kenneth M. Lin,<sup>‡</sup> MD, Danielle Gorelick,<sup>\*</sup> CPNP, Lori A. Asaro,<sup>§</sup> PA-C, MS, and Daniel W. Green,<sup>\*||</sup> MD, MS

*Investigation performed at the Hospital for Special Surgery, New York, New York, USA*

**Background:** There are various reported complications after primary anterior cruciate ligament reconstruction (ACLR) necessitating additional surgery in skeletally immature patients, regardless of technique and autograft type.

**Purpose:** To analyze the rate and type of complications encountered with soft tissue quadriceps tendon autograft (QTA) for ACLR in patients  $\leq 18$  years as well as the overall rate of second surgery, unrelated to the use of the QTA.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** A total of 141 patients  $\leq 18$  years who underwent ACLR with a QTA and had minimum 6-month follow-up were included. All patients underwent ACLR by utilizing a full-thickness soft tissue QTA. Complications associated with the QTA harvest site and use of QTA were reported.

**Results:** The mean age of the included cohort (84 men, 57 women) was  $14.8 \pm 1.6$  years. The average follow-up was of  $2.0 \pm 1.2$  years. A total of 30 (21%) patients had a subsequent complication that required surgical intervention; in 11 (8%) patients, the complication was specifically associated with the use of a QTA, whereas in 19 (13%) patients, the complication was related to the ACLR. In addition, 13 (9%) patients underwent a contralateral ACLR procedure. Of the QTA-related complications, 2 patients developed osteochondritis dissecans (OCD)-like lesions in the superior aspect of the patella, 2 patients had injured their quadriceps extensor mechanism and required surgical repair, and 8 patients had a subsequent procedure to remove nonabsorbable sutures used for donor site quadriceps tendon closure. One of the patients who underwent the removal of nonabsorbable sutures also had an arthroscopic debridement of patellar chondral damage.

**Conclusion:** We reported complications encountered with soft tissue QTA for ACLR. The complication rate for QTA harvest was 8%. However, given that the removal of nonabsorbable sutures from the donor site was caused by the surgical technique used, the revised nonsuture-related complication rate for QTA graft harvest was 2%. Although the use of a QTA has recently gained popularity due to its high return-to-sport and low graft-failure rates, surgeons should be aware of the complications associated with using this graft type.

**Keywords:** anterior cruciate ligament; complication; pediatrics; quadriceps tendon autograft; return to sport

Anterior cruciate ligament (ACL) ruptures in the pediatric and adolescent population have been steadily increasing, and many surgical techniques for ACL reconstruction (ACLR) have been developed for treatment to try to minimize complication rates.<sup>11,29</sup> Complications after primary

ACLR necessitating additional surgery in skeletally immature patients, regardless of technique and autograft type, include growth disturbance, stiffness, graft failure, subsequent meniscus injury, and contralateral ACL rupture.<sup>20,27,35</sup>

A frequent graft choice for the skeletally immature population has been a hamstring tendon autograft (HTA); however, recent studies have demonstrated decreased revision rate with a quadriceps tendon autograft

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(QTA).<sup>2,18,22,33,37</sup> The harvest technique commonly used for a QTA is an open full-thickness soft tissue quadriceps tendon harvest.<sup>1</sup> Few studies have reported long-term outcomes and complications of a QTA harvest for ACLR while promoting preliminary positive outcomes of a QTA.<sup>5,38</sup> These preliminary studies have shown excellent postoperative function, return-to-sport (RTS) rates, and postoperative pain levels equal to or better than other graft choices. However, there is a risk of postoperative complications specifically associated with the use of a QTA. Although many studies have reported on postoperative complications in the adult population, few have investigated complications pediatric patients may face.<sup>5,38,39</sup>

The purpose of this study was to describe the surgical complications and second surgeries encountered after ACLR with soft tissue QTA in pediatric patients  $\leq 18$  years.

## METHODS

### Study Cohort

After receiving institutional review board approval for the study protocol, the senior authors (F.A.C. and D.W.G.) retrospectively reviewed the operative records of all pediatric patients  $\leq 18$  years who underwent ACLR from June 2015 to December 2021 by searching for Current Procedural Terminology code 29888. We included a consecutive series of 143 patients who underwent ACLR with a QTA and had minimum 6-month follow-up data and who participated in competitive, high-risk sports such as football, lacrosse, soccer, or basketball. Patients who were skeletally mature and underwent contralateral ACLR procedures after initial QTA ACLR were excluded from this study. After 3 attempted contacts, 2 (1%) patients were deemed lost to follow-up and excluded from the study, leaving 141 patients in the final analysis. Preoperative demographic information, surgical details, associated diagnosis, and subsequent injuries and complications associated with the quadriceps tendon harvest site and use of QTA that required surgical treatment were collected for all included patients.

### Surgical Technique

In this cohort, the first 100 patients were treated with non-absorbable sutures (Ethibond; Ethicon), and the remaining

41 patients were treated with absorbable sutures (Vicryl; Ethicon).

The surgical technique for the ACLR was determined based on the patient's skeletal maturity. Skeletally immature patients underwent an all-epiphyseal technique whereas patients nearing skeletal maturity underwent a complete transphyseal procedure. All patients underwent ACLR by utilizing a full-thickness soft tissue QTA without a bone plug.<sup>1</sup> In addition, patients who had non-modifiable risk factors and were determined to be at high risk of retear underwent a concomitant a lateral extra-articular tenodesis (LET) with a modified Lemaire technique.<sup>32</sup> Our indications for an LET included those who participated in high-risk competitive sport such as football, lacrosse, soccer, or basketball, grade 3 pivot shift, hyperlaxity (Beighton score  $\geq 4$ ), recurvatum, history of contralateral ACLR, or chronic ACL insufficiency. All patients underwent a quality-of-movement assessment (QMA) before being cleared for RTS.<sup>17</sup>

### Complications

We reported complications associated with the quadriceps tendon harvest site and use of QTA (removal of nonabsorbable sutures from the autograft donor site, quadriceps tendon rupture, and the subsequent development of a superior patellar osteochondritis dissecans [OCD] lesions). Patients were indicated for removal of nonabsorbable sutures from the donor site if they had discomfort that limited physical activity and/or with full flexion and/or extension. ACLR-related complications reported included acquired leg-length discrepancy (LLD) requiring surgical intervention, infection and debridement (I&D), graft rupture, meniscus repair/menisectomy, and lysis of adhesions. In addition, the rate of subsequent contralateral ACLR was reported, but this was not included in the statistical analysis.

### Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) Version 22.0 (IBM). Continuous variables were reported as means and standard deviations, and discrete variables were reported as frequencies and percentages.

<sup>||</sup>Address correspondence to Daniel W. Green, MD, MS, Hospital for Special Surgery, 525 E 70th Street, New York, NY 10021, USA (email: greendw@hss.edu).

\*Pediatric Orthopaedic Service, Hospital for Special Surgery, New York, New York, USA.

<sup>†</sup>Renaissance School of Medicine, Stony Brook University, Stony Brook, New York, USA.

<sup>‡</sup>Department of Sports Medicine, Stanford University Hospital, Palo Alto, California, USA.

<sup>§</sup>Sports Medicine Institute, Hospital for Special Surgery, New York, New York, USA.

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Ethical approval for this study was obtained from the Hospital for Special Surgery (ref No. 2018-1117).

TABLE 1  
Demographic Characteristics of Included Knees<sup>a</sup>

Variable	Total (N = 141)	QTA-Related Complication (n = 11)
Age, y	14.8 ± 1.6	15.0 ± 1.6
Male sex, %	60	73
Procedure		
Primary ACLR	126 (89)	10 (91)
Revision ACLR	15 (11)	1 (9)
ACLR technique		
All-epiphyseal	30 (21)	2 (18)
Complete transphyseal	111 (79)	9 (72)
Concomitant procedure		
Lateral extraarticular tenodesis	101 (72)	11 (100)
Meniscus repair	93 (66)	11 (100)
Hemi-epiphysiodesis	6 (4)	0 (0)
Length of follow-up, y	2.0 ± 1.2	1.9 ± 0.8

<sup>a</sup>Data are reported as mean ± standard deviation or n (%) unless otherwise indicated. ACLR, anterior cruciate ligament reconstruction; QTA, quadriceps tendon autograft.

## RESULTS

The mean age of the 141 included patients was 14.8 ± 1.6 (range, 11-18 years) and 60% were male. The average follow-up time was 2.0 ± 1.2 years (range, 0.5-7.4 years). There were 11 (8%) patients with a subsequent complication associated with the QTA. Baseline demographic characteristics of the overall cohort as well as those with QTA-related complications are summarized in Table 1.

## Complications

A total of 30 (21%) patients had a subsequent complication that required surgical intervention. In addition, 13 (9%) patients underwent ACLR for injuries sustained on the contralateral knee. Table 2 lists the complication rates and subsequent procedures for QTA- and ACLR-related complications.

Of the 11 patients with QTA-related complications, 8 had a subsequent procedure to remove nonabsorbable sutures used for the donor site closure. When we first began to perform QTA ACLR, nonabsorbable sutures were used to close the donor site defect. We encountered a subset of patients who developed persistent donor site irritation and pain associated to the use of such sutures and consequently changed our technique to use absorbable sutures. Nonabsorbable sutures were used in 100 patients the study cohort, making the “true” suture granuloma rate 8%. Given that the removal of nonabsorbable sutures from the donor site in these 8 patients was caused by the surgical technique rather than the graft type, we also calculated the revised nonsuture-related complication rate for QTA graft harvest (2%; n = 3).

Of the remaining 4 patients with QTA-related complications, 2 patients developed OCD-like lesions in the superior aspect of the patella at a mean of 1.2 ± 0.8 years

TABLE 2  
Rates of Complications and Subsequent Surgical Procedures<sup>a</sup>

Complication	Value
QTA-related (n = 11 <sup>b</sup> )	
Removal of nonabsorbable sutures	8 (8 <sup>c</sup> )
OCD-like lesion	2 (1)
Quadriceps tendon rupture	2 (1)
ACLR-related second surgery (n = 19 <sup>b</sup> )	
Acquired leg-length discrepancy	3 (2)
Infection and debridement	2 (1)
Graft rupture upon RTS	2 (1)
Graft rupture before clearance for RTS	3 (2)
Meniscus repair/meniscectomy	6 (4)
Lysis of adhesions	8 (6)
Contralateral ACLR	13 (9)

<sup>a</sup>Data are reported as n (%). ACLR, anterior cruciate ligament reconstruction; OCD, osteochondritis dissecans; QTA, quadriceps tendon autograft; RTS, return to sport.

<sup>b</sup>Some patients underwent concomitant or multiple subsequent procedures that fall into different categories and are represented twice.

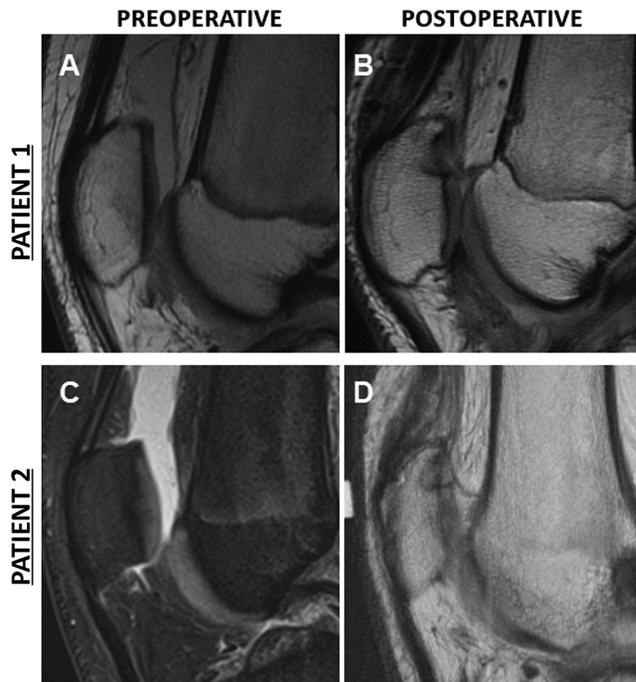
<sup>c</sup>Rate per 100 patients.

postoperatively (Figure 1). One patient was treated operatively and underwent patellar grade 3 chondral damage debridement, whereas the other was treated nonoperatively. Both patients returned to contact sports without limitations. Moreover, 2 patients had quadriceps tendon ruptures after QTA ACLR. The first patient, aged 16, slipped and fell onto a hyperflexed left knee 6 weeks after QTA ACLR and sustained a small bony avulsion injury of the superior pole of the patella. During repair, cultures were taken, and rare *Staphylococcus aureus* were identified. An ultrasound-guided aspiration was positive for *S. aureus*, and the patient subsequently underwent an I&D procedure. This patient returned to running and was cleared for contact sports without limitations. The second patient, aged 14 years, sustained a noncontact injury while playing football 7 months postoperatively before being cleared to RTS. He accidentally slipped on a ball and sustained a complete tear of the distal quadriceps tendon, adjacent to the donor site. He subsequently returned to playing football and was cleared to perform contact sports.

Regarding ACLR-related complications, 3 (2%) patients acquired LLD. Two (1%) patients underwent I&D procedures. Two (1%) patients sustained a graft failure after being cleared for RTS requiring a revision ACLR (3.80 ± 1.95 years after primary ACLR). Three (2%) patients required a revision ACLR when they returned to play before being medically cleared (0.87 ± 0.36 years after primary ACLR). Six (4%) patients had a subsequent meniscus-related surgery and 8 (6%) had a lysis of adhesions procedure.

## DISCUSSION

This cohort of 141 pediatric patients had a complication rate associated with the quadriceps tendon harvest of



**Figure 1.** Development of patellar OCD-like lesion after quadriceps tendon autograft harvest. (A) Preoperative and (B) 13-month postoperative sagittal MRI of a 15-year-old boy. (C) Preoperative and (D) 21-month postoperative sagittal MRI of a 15-year-old boy. Note the superior location of the lesion in (B) and (D).

8%. There were 2 OCD-like lesions, 2 extensor mechanism disruptions, and 8 suture granulomas. Of the 41 patients who were treated with absorbable sutures, none developed a suture granuloma with their quadriceps tendon repair of the harvest site. Interestingly, we reported 1 complication, which, to the best of the authors' knowledge, has not been reported previously: postoperative development of OCD in the superior pole of the patella. Moreover, there were 2 traumatic occurrences of postoperative disturbance of the extensor mechanism that required surgical intervention.

A superior pole patella OCD-like lesion after soft tissue quad tendon harvest has not been described previously. Patellofemoral OCD lesions are far less common than lesions of the weightbearing femoral condyles; within patellofemoral lesions, trochlear lesions are more common than patella lesions.<sup>21</sup> It is known that patella OCD lesions are predominantly found central-inferiorly.<sup>7</sup> While OCD lesions are multifactorial in nature, it has been hypothesized that aberrant vascularity may be a major contributing factor. In both adults and children, the predominant vascular contribution to the patella comes from inferior and inferomedial, with the superolateral quadrant having the least vascular contribution.<sup>14</sup> In assessing regional perfusion, it is known that there is greater contribution from the dorsal half of the patella than the articular half (59% versus 41%), and greater contribution from the outer rim of the patella than the central aspect (62.3% versus 37.7%); however, there is no knowledge specifically of the

central portion of the superior pole, at the area of soft tissue quadriceps tendon harvest.<sup>14</sup> It is unknown whether OCD-like lesions after soft tissue-only quad harvest occur in adults as well. Beyond vascularity, it is possible that osteochondral homeostasis is dependent on baseline load from the pull of the quadriceps. In theory, use of a bone block would predispose further to the development of an OCD-like lesion, but this has not been reported. It is unknown whether graft length plays a role. Similarly, one can speculate that partial thickness harvest may mitigate this phenomenon, but there is no literature to support this. Since identifying these OCD lesions, we have avoided harvesting the quad tendon insertion distally from the dorsal surface of the patella, in an attempt to avoid the potential for vascular compromise.

Moreover, donor-site quadriceps tendon tear after QTA ACLR is an extremely rare major complication. A systematic review conducted by Singh et al<sup>34</sup> recently reported a 0.7% risk (95% confidence interval [CI], 0.3%-1.8%;  $I^2 = 0.00$ ) of this complication happening in the adult population. Their review, which included 55 studies, found that 9 (871 patients) reported on this finding. Before this study, there were only another 2 published incidences of this happening: the first occurring 4 years postoperatively after a new knee trauma, and the second 10 years after ACLR and posterior cruciate ligament reconstruction.<sup>15,26</sup> More recently, Gawel et al<sup>16</sup> reported on a rare case of an adolescent patient who sustained a quadriceps tendon tear of unknown etiology 4 weeks after bone-tendon-bone (BTB) ACLR. Two patients in our cohort sustained traumatic extensor mechanism rupture after QTA ACLR. Although the first instance was a consequence of a fall in a stiff knee, and the second due to sprinting and jumping before sport clearance, it is important for surgeons to be aware of this complication.

Finally, 8% of patients sustained quadriceps tendon harvest site discomfort characterized by persistent site irritation and pain. We associated this with using nonabsorbable Ethibond sutures to close the donor site defect. While a number of *in vivo* studies have reported on the biological reactivity of these materials, the use of nonabsorbable sutures is the gold standard for tendon repairs.<sup>6,12</sup> When testing a variety of nonabsorbable sutures, Carr et al<sup>6</sup> found that Ticron (Tyco) and MagnumWire (Opus Medical) resulted in an intense foreign-body reaction when compared with other similar sutures in a rabbit model. However, they tested them on dorsal fascia, not tendonous tissue. When tested on both muscle tendon tissue and joint capsule, Esenyel et al<sup>12</sup> reported that Ethibond produced the smallest inflammatory response when compared with Fiberwire (Arthrex) and polypropylene (Unilene). Nonetheless, there are several case reports in the literature reporting on the delayed formation of suture granulomas after Ethibond use, ranging from 4 months and up to 7 years postoperatively.<sup>3,19,31</sup> A retrospective case series ( $n = 672$ ) investigating the rate of Ethibond-related suture granuloma formation after Achilles tendon repair in adults, found an incidence rate of 1.6% at a mean of  $6 \pm 3.2$  months after surgery.<sup>10</sup> In our cohort, suture granulomas appeared on average at  $1.67 \pm 0.7$

years postoperatively (range, 6-28 months). An abstract presented at the 2021 Pediatric Research in Sports Medicine annual meeting reported that the use of a QTA in pediatric patients undergoing ACLR was more likely to result in postoperative wound issues when compared with HTA (20.0% versus 2.3%;  $P = .012$ ). However, they did not specify their criteria for wound issues.<sup>4</sup> We speculate that the nonabsorbable sutures irritated the subcutaneous tissue, particularly during the RTS phase with full-speed running and hyperflexion activities, as a mechanical tethering. Once the sutures were removed via minimally invasive “dermatologic” procedure performed under local anesthesia, with sedation, all of the athlete’s donor site symptoms during activity were alleviated. To the best of the authors’ knowledge, we are the first group to report the replicable occurrence of this complication after quadriceps tendon repair, although only 8 of the 100 (8%) patients treated with nonabsorbable suture closure of the donor site developed this complication.

Nonetheless, recent studies have demonstrated excellent clinical and surgical outcomes of QTA in the adult population.<sup>9,23</sup> A 2022 systematic review and meta-analysis comparing QTA, BTB, and HTA by Dai et al<sup>9</sup> including 19,584 adult patients reported that QTA had comparable graft survival and functional outcomes to BTB and HTA and significantly lower donor site morbidity compared with both. Preliminary studies conducted on the pediatric population have yielded similar promising results.<sup>24,30,36,38</sup> Zakharia et al<sup>38</sup> concluded that the use of QTA in skeletally immature patients was associated with lower postoperative complications and comparable clinical and functional outcomes when compared with both BTB and HTA. QTAs for ACLR can be prepared in 2 ways: with a bone plug from the superior pole of the patella (B-QTA), or as an all-soft tissue QTA (S-QTA). However, Crum et al<sup>8</sup> found that, although not statistically significant, the use of a B-QTA featured much wider major and minor complication profiles than S-QTA. Moreover, surgeons must pay careful attention to size, location, and relative depth when harvesting the bone block. Failure to do has been shown to result in higher rates of patellar fracture.<sup>13</sup> While QTA ACLR has been used historically with a B-QTA for revision ACLR, S-QTA has become more popular in the past decade for primary ACLR, and few studies report long-term outcomes and complications in the literature.

Of the 14 studies Zakharia et al<sup>38</sup> examined in their pediatric QTA ACLR systematic review (596 patients), 11 studies reported postoperative complications (487 patients). Postoperative complications included contralateral ACLR (3.9%), graft failure (2.5%), and acquired LLDs (0.6%). Moreover, 2 of the included studies by Ouweleen et al<sup>25</sup> and Pennock et al<sup>28</sup> reported an arthrofibrosis rate of 5% and 6.3%, respectively. The second surgery rate reported in our series (not specific to the QTA harvest) compares favorably with the literature. A total of 19 (13%) patients had complications related to the following factors, as noted in Table 2: 1% acquired LLD, 1% I&D, 1% graft rupture after QMA and clearance for RTS, 2% graft rupture due to noncompliance before QMA

clearance for RTS, 4% meniscus surgery, and 6% arthrofibrosis rate. Our rate of contralateral ACLR was 9%, 3 times that reported by Zakharia et al.<sup>38</sup> We believe this was a result of having a cohort of active pediatric patients at high risk of retear. Of the 13 patients who underwent a contralateral ACLR, 9 (70%) had a concomitant LET procedure performed for their primary injury. Interestingly, Zakharia et al<sup>38</sup> found no incidents of quadriceps tendon harvest site complications, postoperative quadriceps tendon rupture, or subsequent development of OCD-like lesions.

### Limitations

There are several limitations to this study. First, there is selection bias as the surgeons indicated all of these patients for a QTA ACLR, and additionally, the change in surgical technique with regard to the use of nonabsorbable sutures similarly introduces selection bias. In addition, this study was conducted at a single institution, analyzing the complications of only 2 surgeons. Moreover, this study does not have the long-term follow-up to fully understand the clinical implications of these complications.

### CONCLUSION

In this study, we report complications encountered with soft tissue QTA for ACLR in a high-risk cohort of 141 adolescent athletes. The complication rate for this cohort was 8%. Clearly, the use of nonabsorbable sutures for donor site closure was, in retrospect, an error in technique and increased the comprehensive QTA complication rate from 2% to 8%.

As a result of our clinical experience, we would strongly recommend against the use of nonabsorbable sutures for donor site closure. We have described an unusual complication of the development of a superior patella OCD after all soft tissue QTA harvest. Although the use of a QTA has recently gained popularity due to its high RTS and low graft failure rate, surgeons must be aware of the complications and risk associated with this procedure.

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