Quadriceps Tendon Anterior Cruciate Ligament Reconstruction in Skeletally Immature Patients

3-Year Clinical and Patient-Reported Outcomes

Frank A. Cordasco,*† MD, MS, Sofia Hidalgo Perea,‡ BS, Tyler J. Uppstrom,* MD, Danielle E. Chipman,‡ BS, Nicolas Pascual-Leone,‡ MD, Alexandra Hunter Aitchison,‡ BS, Emilie Lijesen,‡ BS, Lori Ann Asaro,*† PA-C, MS, and Daniel W. Green,*‡§ MD, MS
Investigation performed at Hospital for Special Surgery, New York, New York, USA

Background: The rate of anterior cruciate ligament (ACL) rupture in active, skeletally immature patients is increasing. Although hamstring tendon autograft (HTA) was previously deemed the gold standard, recent studies have shown HTA to have a high failure rate in this high-risk population of young competitive athletes, and quadriceps tendon autograft (QTA) has yielded excellent preliminary outcomes in some studies examining this population.

Purpose: To evaluate 3-year clinical and patient-reported functional outcomes of primary ACL reconstruction (ACLR) with soft tissue QTA in skeletally immature patients.

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

Methods: Skeletally immature patients who underwent ACLR with a full-thickness soft tissue QTA were included. Preoperative patient and surgical data were collected. The ACLR technique was selected predicated upon skeletal age and included all-epiphyseal and complete transphyseal techniques. Patients were followed for a minimum of 2 years with successive clinical visits or were contacted via telephone. Patients who did not have minimum 2-year follow-up after 3 contact attempts via telephone were excluded. Information regarding return to sports (RTS) and concomitant or subsequent surgical procedures was collected. Pediatric International Knee Documentation Committee (Pedi-IKDC), Hospital for Special Surgery Functional Activity Brief Scale (HSS Pedi-FABS), and Single Assessment Numeric Evaluation (SANE) scores were collected.

Results: Of 85 adolescent patients aged 11.1 to 17.6 years (mean age, 14.1 ± 1.2 years), 2 patients were determined to be lost to follow-up after 3 failed contact attempts. Of the patients included in this study (N = 83), 26 patients (31%) underwent all-epiphyseal and 57 patients (69%) underwent complete transphyseal ACLR. Additionally, 48 patients (58%) underwent concomitant lateral extra-articular tenodesis using the iliotibial band with a modified Lemaire technique. The mean follow-up time was 3.7 ± 1.2 years (range, 2-7 years). Twenty (24%) patients had subsequent surgical procedures, of which 3 (4%) were due to graft failures. At a mean 3-year follow-up, the mean Pedi-IKDC, HSS Pedi-FABS, and SANE scores were 90, 23, and 94 respectively; the RTS rate was 100%; and the rate of RTS at the previous level of performance was 93%.

Conclusion: Use of a soft tissue QTA for ALCR in a high-risk skeletally immature population of athletes resulted in excellent postoperative outcomes with low rates of graft failure and high return to sport rates.

Keywords: anterior cruciate ligament; pediatric; quadriceps tendon autograft; knee

Over the past several decades, the incidence of anterior cruciate ligament (ACL) injuries in skeletally immature patients has continued to increase.[3,12,46] Numerous studies have demonstrated increased risk of meniscal and cartilage damage and lower rates of return to play with delayed surgical or nonoperative treatment in these young, active patients.[25,30] As such, the rate of ACL reconstruction (ACLR) performed in skeletally immature patients also continues to rise.[12,15]

When ACLR is performed in skeletally immature patients, graft selection is essential to patient function and outcomes.[10,15] Allograft is largely avoided in this population due to high rates of graft failure. A number of other graft options exist, including hamstring tendon autograft (HTA), iliotibial band autograft, and quadriceps tendon autograft (QTA).[8,10] However, similar to the existing literature on ACLR technique, there is currently no consensus on the optimal graft choice for these patients.[16]

The American Journal of Sports Medicine
2024;52(9):2230–2236
DOI: 10.1177/03635465241255641

Historically, HTA has been the graft of choice for ACLR in skeletally immature patients, with overall good outcomes.[6,9,22] Several recent studies have reported use of HTA in up to 65% of ACLRs performed in skeletally immature patients between 1985 and 2016.[26,47] However, concerns exist regarding graft failure, with reported graft failure rates of 5% to 25% after ACLR with HTA in skeletally immature patients. As a result, there is increased interest in alternative graft choices.[4,5,8-11,36]

One alternative graft option is QTA. In the studies on adult patients, clinical and functional outcomes of ACLR with QTA are similar to those of HTA and bone–patellar tendon–bone (BPTB) autograft, with low donor-site morbidity.[7,31,32,43] However, few studies have reported long-term outcomes associated with ACLR with QTA in skeletally immature patients.[24,27,35,45]

The purpose of the current study was to evaluate clinical outcomes and patient-reported outcomes (PROs) at minimum 2-year follow-up in skeletally immature patients who underwent ACLR with soft tissue QTA. We hypothesized that the use of soft tissue QTA in both complete transphyseal and all-epiphyseal ACLR would provide good PROs and functional outcomes, with low graft failure rates and high rate of return to sports (RTS).

METHODS

Study Cohort

A retrospective review of all patients who underwent ACLR performed by the senior authors (F.A.C., D.W.G.) between 2015 and 2020 was conducted upon institutional review board approval. A series of consecutive skeletally immature patients who underwent ACLR with soft tissue QTA with follow-up $\geq$24 months were reviewed. Preoperative patient information, surgical details, associated diagnoses, and outcome measures were collected for each patient. The smallest graft tunnel socket size (ie, femoral vs tibial) was reported. Patients who did not have minimum 24-month follow-up after 3 contact attempts via telephone were excluded. The length of follow-up was determined by the last clinic visit date or the date of postoperative PRO completion.

Surgical Technique

The surgical technique used in this cohort involved harvesting a full-thickness soft tissue QTA without a bone plug, as previously described.[2] All cases were performed in patients with open femoral physes. The ACLR technique (either all-epiphyseal or complete transphyseal) was selected predicated upon skeletal age.[6] Skeletally immature patients with $\geq$3 years of growth remaining underwent an all-epiphyseal technique as previously described.[28] For patients with nearly closed femoral physes, a standard complete transphyseal procedure was performed. Additionally, per surgeon discretion, a concomitant modified Lemaire lateral extra-articular tenodesis was performed in patients who participated in high-risk competitive sports and had grade 3 pivot shift, hyperlaxity (Beighton score >4), recurvatum, increased posterior lateral tibial slope, narrow notch width, contralateral ACLR, or chronic ACL insufficiency.[18,39]

Postoperative Rehabilitation

The postoperative protocol consisted of 2 weeks in a hinged knee brace locked in extension for ambulation and 4 to 6 weeks of progressive weightbearing with crutches for support. Range of motion was initiated immediately after surgery, with the goal of achieving 90° of flexion in the first 2 weeks postoperatively. Physical therapy for range of motion and strengthening was initiated at 2 weeks postoperatively. A supervised functional progression to running and jumping was initiated at 6 months postoperatively, with a quality of motion assessment before RTS.[17]

Outcome Measures

Patients were followed with successive clinical visits or were contacted via telephone. Preoperatively, patients completed the Pediatric International Knee Documentation Committee (Pedi-IKDC) questionnaire and the Hospital for Special Surgery Functional Activity Brief Scale (HSS Pedi-FABS).[13,23] At a minimum 2-year follow-up, patients completed the Pedi-IKDC, the HSS Pedi-FABS, and the Single Assessment Numeric Evaluation (SANE).[42] Information regarding RTS and subsequent surgical procedures was also collected.

Statistical Analysis

Statistical analyses were performed using the Statistical Product and Service Solution (SPSS) Version 22.0 (IBM Corp). Means and standard deviations were used to report continuous variables, whereas discrete variables were reported as frequencies and percentages. The Fisher exact

§Address correspondence to Daniel W. Green, MD, MS, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA (email: greendw@hss.edu).
*Department of Orthopedic Surgery, Hospital for Special Surgery, New York, New York, USA.
†Sports Medicine Institute, Hospital for Special Surgery, New York, New York, USA.
‡Pediatric Orthopedic Surgery Service, Hospital for Special Surgery, New York, New York, USA.
Submitted December 15, 2023; accepted April 16, 2024.
One or more of the authors has declared the following potential conflict of interest or source of funding: F.A.C. has received royalties from Arthrex, Saunders Mosby Elsevier, and Wolters-Kluwer Health Lippincott Williams and Wilkins; consulting fees from Arthrex; and support for education from Gotham Surgical Solutions & Devices. D.W.G. has received royalties and consulting fees from Arthrex, royalties from Pega Medical, speaking fees from Synthes, and hospitality payments from OrthoPediatrics. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

TABLE 1
Patient and Clinical Characteristics[a]

Variable	All Patients (N = 83)	AE Cohort (n = 26)	CT Cohort (n = 57)
Age, y	14.1 ± 1.2	13.1 ± 0.9	14.5 ± 1.0
Sex			
Male	52 (62)	19 (73)	33 (48)
Female	31 (38)	7 (27)	24 (42)
Bone age, y			
Male	14.3 ± 1.4	13.1 ± 1.0	15.1 ± 1.0
Female	13.6 ± 1.0	12.9 ± 1.0	13.8 ± 1.0
Length of follow-up, y	3.7 ± 1.2	4.0 ± 1.2	3.6 ± 1.2
ACLR technique			
Primary	80 (96)	25 (96)	55 (96)
Revision	3 (4)	1 (4)	2 (4)
Graft tunnel socket size, mm	10.4 ± 2.2	9.6 ± 1.4	9.8 ± 0.7
Concomitant procedure			
Lateral extra-articular tenodesis	48 (58)	13 (50)	35 (61)
Meniscal procedure	51 (65)	14 (54)	37 (65)
Debridement	1 (1)	1 (4)	0 (0)
Repair	48 (58)	13 (50)	35 (61)
Debridement and repair	2 (2)	1 (4)	1 (2)
Hemiepiphysiodesis	5 (6)	3 (12)	2 (4)

[a]Data are expressed as mean ± SD or n (%). ACLR, anterior cruciate ligament reconstruction; AE, all-epiphyseal; CT, complete transphyseal.

test was used to compare frequency of reoperation rates between groups. Pre- and postoperative PRO scores were compared using a 2-sample t test with statistical significance set at $P < .05$.

RESULTS

Of a total of 85 adolescent patients aged 11.1 to 17.6 years (mean age, 14.1 ± 1.2 years) identified from medical records, 2 patients were determined to be lost to follow-up after 3 failed contact attempts. Of the patients included in this study (N = 83), 26 (31%) underwent all-epiphyseal ACLR and 57 (69%) underwent complete transphyseal ACLR. Additionally, 48 patients (58%) underwent concomitant lateral extra-articular tenodesis using iliotibial band autograft via a modified Lemaire technique. The mean follow-up time was 3.7 ± 1.2 years (range, 2-7 years). Patient and clinical data are summarized in Table 1.

Twenty patients (24%) required subsequent surgical procedures, of which 6 were meniscal procedures with an intact ACL graft, 5 were lysis of adhesions, 4 were nonabsorbable QTA donor-site suture removals, 3 were irrigation and debridement, 2 were procedures due to an acquired leg-length discrepancy, and 3 were revision ACLRs due to QTA failure, 2 of which were secondary to complete transphyseal technique and 1 to an all-epiphyseal technique (Table 2). No significant difference was found in reoperation rates between all-epiphyseal and complete transphyseal cohorts ($P = .17$) or between those who underwent concomitant lateral extra-articular tenodesis procedure ($P = .61$). None of the patients who had an infection and debridement underwent revision ACLR. Fourteen patients (17%) underwent ACLR for injuries sustained on the contralateral knee, and 5 patients (6%) underwent removal of hardware for hemiepiphysiodesis. Three patients (4%) had femoral growth arrests and developed an acquired leg-length discrepancy after all-epiphyseal ACLR. Two of these patients sought surgical correction and are thus represented in Table 2, and 1 patient did not require surgical correction. One patient developed an osteochondritis dissecans lesion in the superior aspect of the patella postoperatively, which was treated nonoperatively.

Preoperative PRO completion included the Pedi-IKDC for 47 patients (57%) and HSS Pedi-FABS for 69 patients (83%). Postoperative PRO completion included the Pedi-IKDC for 59 patients (71%), HSS Pedi-FABS for 60 patients (72%), and SANE for 70 patients (84%). Both the Pedi-IKDC and the HSS Pedi-FABS scores increased significantly after QTA ACLR. Preoperatively, the mean Pedi-IKDC score was 51 and the mean HSS Pedi-FABS score was 20. At a mean 3-year follow-up, the mean Pedi-IKDC score significantly increased to 90 ($P < .0001$), and the mean HSS Pedi-FABS score significantly increased to 23 ($P = .03$). At a mean of 3 years after surgery, the mean SANE score was 94, and 100% of patients reported returning to sports, with 93% reporting returning to the previous level of sports performance (Table 3).

DISCUSSION

This study sought to evaluate 2-year clinical outcomes and PROs after primary ACLR with soft tissue QTA in skeletally immature patients, procedures that were performed by the 2 senior surgeons together (F.A.C., D.W.G.). This essentially represents a single-surgeon series of patients treated in a standardized fashion regarding preoperative,

TABLE 2
Subsequent Surgeries of the Included Cohort[a]

	All Patients (N = 83)	AE Cohort (n = 26)	CT Cohort (n = 57)	*P*
Second surgical procedure	20 (24)	11 (42)	9 (16)	.17
Meniscectomy/meniscal repair	6 (7)	2 (8)	4 (7)	
Lysis of adhesions	5 (6)	4 (15)	1 (2)	
Nonabsorbable QTA donor-site suture removal	4 (5)	1 (4)	3 (5)	
Irrigation and debridement	3 (4)	1 (4)	2 (4)	
Revision ACLR	3 (4)	1 (4)	2 (4)	
Leg length discrepancy	2 (2)	2 (8)	0 (0)	
Contralateral ACL surgery	14 (17)	2 (8)	12 (21)	

[a]Data are expressed as n (%). Of note, these procedures are not mutually exclusive. ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; AE, all-epiphyseal; CT, complete transphyseal; QTA, quadriceps tendon autograft.

TABLE 3
Patient-Reported Outcomes After Anterior Cruciate Ligament Reconstruction With Quadriceps Tendon Autograft[a]

Outcome Measure	Preoperative	Postoperative	*P*
Pedi-IKDC	51 ± 17 (RR, 57%)	90 ± 14 (RR, 71%)	<.0001
HSS Pedi-FABS	20 ± 11 (RR, 83%)	23 ± 6 (RR, 72%)	.03
SANE		94 ± 7 (RR 84%)	
RTS, n (%)		83 (100)	
RTS at the previous level of performance, n (%)		78 (93)	

[a]Values are expressed as mean ± SD unless otherwise noted. Pedi-IKDC and SANE are scored 0 to 100 (100 meaning no symptoms or disability). HSS Pedi-FABS is scored 0 to 30 (30 meaning fully active). HSS Pedi-FABS, Hospital for Special Surgery Functional Activity Brief Scale; Pedi-IKDC, Pediatric International Knee Documentation Committee score; RR, response rate; RTS, return to sports; SANE, Single Assessment Numeric Evaluation.

intraoperative, and postoperative phases including the rehabilitation and RTS phases. Our results demonstrated a 4% ACL retear rate at a mean 3-year follow-up among this cohort of patients. Moreover, patients reported excellent objective and subjective outcomes, reporting mean Pedi-IKDC, HSS Pedi-FABS, and SANE scores of 90, 23, and 94, respectively, and a 93% rate of RTS at the preoperative level, supporting our initial hypothesis.

Given the increasing incidence of ACL injuries in skeletally immature patients, improving surgical techniques for ACLR has been at the forefront of pediatric orthopaedic research.[12,15] Graft selection has been shown to play a crucial factor in the success of ACLR.[4,5,8-11,36] Although HTA was historically the preferred graft choice, reports of higher failure rates in this high-risk cohort of skeletally immature athletes resulted in transitioning to the QTA as an alternative.[6] Recent studies have shown QTA to yield superior preliminary outcomes in the adolescent and pediatric population.[18,33,37,38,44] Aitchison et al[1] showed that at 1 year postoperatively, QTA demonstrated improved graft maturation, remodeling, and structural integrity on magnetic resonance imaging compared with HTA in pediatric patients. Although preliminary, these results highlight the feasibility of QTA compared with HTA in pediatric patients.

At a mean 3-year follow-up, we found a failure rate of 4% in this cohort of 83 skeletally immature patients. These results are significantly better compared with the results of HTA ACLR in this cohort of patients. A recently published systematic review by Zakharia et al[48] reported a retear rate of 2.5% in 408 cases of pediatric QTA ACLR included in the review, consistent with our results and lower than retear rates associated with HTA. Similarly, in a 2023 systematic review and meta-analysis comparing clinical outcomes of pediatric patients who had undergone QTA versus HTA ACLR with a minimum 2-year follow-up, Rangasamy et al[37] found retear rates of 3.5% versus 12.4%, respectively. Pennock et al[35] compared outcomes of transphyseal ACLR with HTA versus QTA in 83 skeletally immature patients (56 HTA, 27 QTA), demonstrating significantly larger diameters for QTA ($P < .001$), with a significantly higher retear rate in patients who underwent ACLR with HTA (21%) versus QTA (4%). PROs and functional scores were similar between the 2 groups. Of note, this systematic review[35] included both soft tissue QTA and QTA with a patellar bone block, the latter of which has shown to have a higher risk of growth disturbance in pediatric patients with open physes.[20,27,29,41] In addition, patellar fracture has been reported as a complication associated with bone-QTA.[14] Due to concerns about donor-site morbidity associated with bone block harvest in these young patients, our preferred technique uses an all–soft tissue QTA.

Of the 20 patients undergoing a second operation in the current study, 6 underwent meniscal surgery in the

presence of an intact graft. The senior surgeons' approach to skeletally immature athletes with an ACL tear and associated meniscal pathology is to err on the side of repairing the majority of meniscal tears given the natural history of partial meniscectomy in a young cohort. As such, occasionally meniscal repairs fail, necessitating further surgery. The senior authors believe that this is justified considering the alternative, and unfortunately this factor represents 30% of the second surgeries. Additionally, the quadriceps tendon donor site in the earlier cases in this series was closed with nonabsorbable suture. This resulted in 4 of the 20 patients undergoing a second surgery for suture removal, representing 20% of the second surgeries. The senior authors transitioned to absorbable sutures subsequently.[19] This iatrogenic origin of a second surgery is no longer a clinical issue.

Clinical outcomes and PROs after QTA may be superior to those after ACLR with BPTB autograft or HTA. A systematic review conducted by Hurley et al[21] demonstrated that QTA resulted in a lower incidence of anterior knee pain when compared with BPTB autograft and no difference when compared with HTA. Mouarbes et al[31] reported similar rates of graft failure among all graft types in a systematic review and meta-analysis of 2856 knees but lower donor-site morbidity in patients who underwent QTA versus BPTB procedures and better Lysholm scores in patients who underwent QTA versus HTA procedures. In a systematic review that included 596 pediatric patients, Zakharia et al[48] reported no persistent anterior knee pain after QTA ACLR. Moreover, they reported a mean postoperative IKDC score that ranged from 75.9 to 94.0. Similarly, Rangasamy et al[37] reported that mean Lysholm scores after QTA ACLR in pediatric patients were significantly higher ($P < .001$) than those after HTA ACLR. Our study found excellent PROs, with significantly improved Pedi-IKDC and HSS Pedi-FABS scores of 90 and 23, respectively, and a SANE score of 94 with a 100% RTS rate and a 93% rate of RTS at the previous level of performance, consistent with the existing literature.

Previous studies have raised concern about the development of cyclops lesions and arthrofibrosis after ACLR with QTA. A systematic review by Zhang et al[49] reported 16 cyclops lesions (2.8%) among 16 soft tissue QTA studies (570 patients). Similarly, of the 11 included studies (487 patients) that reported postoperative complications in their systematic review, Zakharia et al[48] reported 10 cases (2.1%) of revision surgery for arthrofibrosis. Moreover, in a cohort of 378 pediatric patients (103 HTA, 180 BPTB, 95 QTA), Ouweleen et al[34] reported that BPTB autograft resulted in a statistically significant higher rate of arthrofibrosis than QTA and HTA (10%, 6.3%, and 1.9%, respectively). However, in a 2021 study that included 475 skeletally mature patients (252 HTA, 223 QTA), Schmücker et al[40] found a non–statistically significant trend for QTA patients to be at higher risk of reoperation due to cyclops lesions when compared with HTA patients (5.0% vs 2.4%, respectively; $P = .13$). In the current study, 5 patients (6%) underwent subsequent lysis of adhesions, a rate that is slightly higher when compared with data on skeletally mature patients.

This study has several limitations. Due to its retrospective nature, not all patients had complete data available for review. Five patients were excluded from calculating the socket size, and 2 patients were excluded from calculating bone age. Preoperatively, 47 (57%) patients completed the Pedi-IKDC and 69 (83%) completed the HSS Pedi-FABS. Postoperatively, 59 (71%) patients completed the Pedi-IKDC, 60 (72%) completed the HSS Pedi-FABS, and 70 (84%) completed the SANE PRO. Additionally, although this study included clinical outcomes and PROs, there was no control group for comparison. Last, this cohort was obtained from a single institution, and the surgeries were performed by 2 surgeons together and therefore may not be generalizable. Further longitudinal studies should investigate outcomes after ACLR with QTA in comparison with alternative graft types to directly compare long-term outcomes.

CONCLUSION

This study demonstrated a low rate of graft failure (4%), an excellent RTS rate (100%), and an excellent rate of RTS at the previous level of performance (93%) after ACLR with QTA in skeletally immature patients, especially when compared with previously reported studies of ACLR with HTA. To our knowledge, this is the first study to describe short-term outcomes of ACLR with a soft tissue QTA in the high-risk pediatric patient population.

REFERENCES

1. Aitchison AH, Alcoloumbre D, Mintz DN, et al. MRI signal intensity of quadriceps tendon autograft and hamstring tendon autograft 1 year after anterior cruciate ligament reconstruction in adolescent athletes. *Am J Sports Med*. 2021;49(13):3502-3507.
2. Aitchison AH, Schlichte LM, Green DW, Cordasco FA. Open full-thickness quadriceps tendon autograft harvest with repair for anterior cruciate ligament reconstruction. *Arthrosc Tech*. 2020;9(10):e1459-e1465.
3. Buller L, Best M, Baraga M, Kaplan L. Trends in anterior cruciate ligament reconstruction in the United States. *Orthop J Sports Med*. 2014;3(1):2325967114563664.
4. Calvo R, Figueroa D, Gili F, et al. Transphyseal anterior cruciate ligament reconstruction in patients with open physes: 10-year follow-up study. *Am J Sports Med*. 2015;43(2):289-294.
5. Cassard X, Cavaignac E, Maubisson L, Bowen M. Anterior cruciate ligament reconstruction in children with a quadrupled semitendinosus graft: preliminary results with minimum 2 years of follow-up. *J Pediatr Orthop*. 2014;34(1):70-77.
6. Cordasco F, Black S, Price M, et al. Return to sport and reoperation rates in patients under the age of 20 after primary anterior cruciate ligament reconstruction: risk profile comparing 3 patient groups predicated upon skeletal age. *Am J Sports Med*. 2019;47(3):628-639.
7. Crum R, Kay J, Lesniak B, Getgood A, Musahl V, de Sa D. Bone versus all soft tissue quadriceps tendon autografts for anterior cruciate ligament reconstruction: a systematic review. *Arthroscopy*. 2021;37(3):1040-1052.

8. Cruz A, Beck J, Ellington M, et al. Failure rates of autograft and allograft ACL reconstruction in patients 19 years of age and younger: a systematic review and meta-analysis. *JBJS Open Access*. 2020;5(4):e20.00106-e20.00106.
9. Cruz AI, Fabricant PD, McGraw M, Rozell JC, Ganley TJ, Wells L. All-epiphyseal ACL reconstruction in children: review of safety and early complications. *J Pediatr Orthop*. 2017;37(3):204-209.
10. Dekker T, Rush J, Schmitz M. What's new in pediatric and adolescent anterior cruciate ligament injuries? *J Pediatr Orthop*. 2018;38(3):185-192.
11. Demange M, Camanho G. Nonanatomic anterior cruciate ligament reconstruction with double-stranded semitendinosus grafts in children with open physes: minimum 15-year follow-up. *Am J Sports Med*. 2014;42(12):2926-2932.
12. Dodwell ER, Lamont LE, Green DW, Pan TJ, Marx RG, Lyman S. 20 years of pediatric anterior cruciate ligament reconstruction in New York state. *Am J Sports Med*. 2014;42(3):675-680.
13. Fabricant PD, Robles A, Downey-Zayas T, et al. Development and validation of a pediatric sports activity rating scale: the Hospital for Special Surgery Pediatric Functional Activity Brief Scale (HSS Pedi-FABS). *Am J Sports Med*. 2013;41(10):2421-2429.
14. Fu FH, Rabuck SJ, West RV, Tashman S, Irrgang JJ. Patellar fractures after the harvest of a quadriceps tendon autograft with a bone block: a case series. *Orthop J Sports Med*. 2019;7(3): 2325967119829051.
15. Fury MS, Paschos NK, Fabricant PD, et al. Assessment of skeletal maturity and postoperative growth disturbance after anterior cruciate ligament reconstruction in skeletally immature patients: a systematic review. *Am J Sports Med*. 2022;50(5):1430-1441.
16. Gebhard F, Ellermann A, Hoffmann F, Jaeger J, Friederich N. Multicenter-study of operative treatment of intraligamentous tears of the anterior cruciate ligament in children and adolescents: comparison of four different techniques. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(9):797-803.
17. Graziano J, Chiaia T, De Mille P, Nawabi DH, Green DW, Cordasco FA. Return to sport for skeletally immature athletes after ACL reconstruction: preventing a second injury using a quality of movement assessment and quantitative measures to address modifiable risk factors. *Orthop J Sports Med*. 2017;5(4):2325967117700599.
18. Green DW, Hidalgo Perea S, Brusalis CM, Chipman DE, Asaro LA, Cordasco FA. A modified Lemaire lateral extra-articular tenodesis in high-risk adolescents undergoing anterior cruciate ligament reconstruction with quadriceps tendon autograft: 2-year clinical outcomes. *Am J Sports Med*. 2023;51(6):1441-1446.
19. Hidalgo Perea S, Chipman DE, Cordasco FA, et al. Association of quadriceps tendon harvest for ACL reconstruction with development of osteochondritis dissecans of the patella in pediatric patients. *Orthop J Sports Med*. 2024;12(2):23259671231219712.
20. Houle JB, Letts M, Yang J. Effects of a tensioned tendon graft in a bone tunnel across the rabbit physis. *Clin Orthop Relat Res*. 2001;391:275-281.
21. Hurley E, Calvo-Gurry M, Withers D, Farrington S, Moran R, Moran C. Quadriceps tendon autograft in anterior cruciate ligament reconstruction: a systematic review. *Arthroscopy*. 2018;34(5):1690-1698.
22. Kocher M, Smith J, Zoric B, Lee B, Micheli L. Transphyseal anterior cruciate ligament reconstruction in skeletally immature pubescent adolescents. *J Bone Joint Surg Am*. 2007;89(12):2632-2639.
23. Kocher MS, Smith JT, Iversen MD, et al. Reliability, validity, and responsiveness of a modified International Knee Documentation Committee Subjective Knee Form (Pedi-IKDC) in children with knee disorders. *Am J Sports Med*. 2011;39(5):933-939.
24. Kohl S, Stutz C, Decker S, et al. Mid-term results of transphyseal anterior cruciate ligament reconstruction in children and adolescents. *Knee*. 2014;21(1):80-85.
25. Kolin D, Dawkins B, Park J, et al. ACL reconstruction delay in pediatric and adolescent patients is associated with a progressive increased risk of medial meniscal tears. *J Bone Joint Surg Am*. 2021;103(15):1368-1373.
26. Longo U, Ciuffreda M, Casciaro C, et al. Anterior cruciate ligament reconstruction in skeletally immature patients: a systematic review. *Bone Joint J*. 2017;99(8):1053-1060.
27. Mauch C, Arnold M, Wirries A, Mayer R, Friederich N, Hirschmann M. Anterior cruciate ligament reconstruction using quadriceps tendon autograft for adolescents with open physes—a technical note. *Sports Med Arthrosc Rehabil Ther Technol*. 2011;3(1):7.
28. McCarthy MM, Graziano J, Green DW, Cordasco FA. All-epiphyseal, all-inside anterior cruciate ligament reconstruction technique for skeletally immature patients. *Arthrosc Tech*. 2012;1:e231-e239.
29. Meller R, Kendoff D, Hankemeier S, et al. Hindlimb growth after a transphyseal reconstruction of the anterior cruciate ligament: a study in skeletally immature sheep with wide-open physes. *Am J Sports Med*. 2008;36(12):2437-2443.
30. Millett P, Willis A, Warren R. Associated injuries in pediatric and adolescent anterior cruciate ligament tears: does a delay in treatment increase the risk of meniscal tear? *Arthroscopy*. 2002;18(9):955-959.
31. Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: a systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone–patellar tendon–bone and hamstring-tendon autografts. *Am J Sports Med*. 2019;47(14):3531-3540.
32. Mulford J, Hutchinson S, Hang J. Outcomes for primary anterior cruciate reconstruction with the quadriceps autograft: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(8):1882-1888.
33. Nyland J, Collis P, Huffstutler A, et al. Quadriceps tendon autograft ACL reconstruction has less pivot shift laxity and lower failure rates than hamstring tendon autografts. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(2):509-518.
34. Ouweleen AJ, Hall TB, Finlayson CJ, Patel NM. Predictors of arthrofibrosis after pediatric anterior cruciate ligament reconstruction: what is the impact of quadriceps autograft? *J Pediatr Orthop*. 2021; 41(7):395-399.
35. Pennock A, Johnson K, Turk R, et al. Transphyseal anterior cruciate ligament reconstruction in the skeletally immature: quadriceps tendon autograft versus hamstring tendon autograft. *Orthop J Sports Med*. 2019;7(9):2325967119872450.
36. Peterson D, Ayeni O. Pediatric anterior cruciate ligament reconstruction outcomes. *Curr Rev Musculoskelet Med*. 2016;9(4):339-347.
37. Rangasamy K, Baburaj V, Gopinathan NR, Dhillon MS, Parikh SN. Quadriceps tendon autograft is promising with lower graft rupture rates and better functional Lysholm scores than hamstring tendon autograft in pediatric ACL reconstruction: a systematic review and meta-analysis. *J Orthop*. 2023;49:156-166.
38. Runer A, Csapo R, Hepperger C, Herbort M, Hoser C, Fink C. Anterior cruciate ligament reconstructions with quadriceps tendon autograft result in lower graft rupture rates but similar patient-reported outcomes as compared with hamstring tendon autograft: a comparison of 875 patients. *Am J Sports Med*. 2020;48(9):2195-2204.
39. Schlichte LM, Aitchison AH, Green DW, Cordasco FA. Modified Lemaire lateral extra-articular tenodesis in the pediatric patient: an adjunct to anterior cruciate ligament reconstruction. *Arthrosc Tech*. 2020;9(1):e111-e116.
40. Schmücker M, Haraszuk J, Hölmich P, Barfod K. Graft failure, revision ACLR, and reoperation rates after ACLR with quadriceps tendon versus hamstring tendon autografts: a registry study with review of 475 patients. *Am J Sports Med*. 2021;49(8):2136-2143.
41. Seil R, Pape D, Kohn D. The risk of growth changes during transphyseal drilling in sheep with open physes. *Arthroscopy*. 2008;24(7):824-833.
42. Shelbourne KD, Barnes AF, Gray T. Correlation of a single assessment numeric evaluation (SANE) rating with modified Cincinnati Knee Rating System and IKDC subjective total scores for patients after ACL reconstruction or knee arthroscopy. *Am J Sports Med*. 2012;40(11):2487-2491.
43. Slone HS, Romine SE, Premkumar A, Xerogeanes JW. Quadriceps tendon autograft for anterior cruciate ligament reconstruction: a comprehensive review of current literature and systematic review of clinical results. *Arthroscopy*. 2015;31(3):541-554.

44. Todor A, Nistor DV, Caterev S. Clinical outcomes after ACL reconstruction with free quadriceps tendon autograft versus hamstring tendons autograft: a retrospective study with a minimal follow-up two years. *Acta Orthop Traumatol Turc*. 2019;53(3):180-183.
45. Vaughn N, Dunleavy M, Jackson T, Hennrikus W. The outcomes of quadriceps tendon autograft for anterior cruciate ligament reconstruction in adolescent athletes: a retrospective case series. *Eur J Orthop Surg Traumatol*. 2022;32(4):739-744.
46. Werner B, Yang S, Looney A, Gwathmey F. Trends in pediatric and adolescent anterior cruciate ligament injury and reconstruction. *J Pediatr Orthop*. 2016;36(5):447-452.
47. Wong S, Feeley B, Pandya N. Complications after pediatric ACL reconstruction: a meta-analysis. *J Pediatr Orthop*. 2019;39(8):e566-e571.
48. Zakharia A, Lameire DL, Abdel Khalik H, et al. Quadriceps tendon autograft for pediatric anterior cruciate ligament reconstruction results in promising postoperative function and rates of return to sports: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(11):3659-3672.
49. Zhang K, Beshay T, Murphy B, Sheean A, de Sa D. Systematic review quadriceps tendon anterior cruciate ligament reconstruction: a systematic review of postoperative rehabilitation and complication profiles. *Arthroscopy*. 2022;38(6):2062-2072.