Comparison of Arthrofibrosis After ACL Reconstruction According to Graft Choice

Quadriceps Tendon Versus Bone-Patellar Tendon-Bone Autograft

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Background: Arthrofibrosis is a complication of anterior cruciate ligament reconstruction (ACLR), and it is possible that graft choice such as the quadriceps tendon (QT) autograft may be a risk factor. With the increasing popularity of the QT autograft, it is important to compare it with other graft choices.

Purpose/Hypothesis: The purpose of this study was to identify whether graft choice, QT versus bone–patellar tendon–bone (BTB) autograft, is a risk factor for early return to the operating room for arthrofibrosis after ACLR. It was hypothesized that the rate of arthrofibrosis surgery would be higher for the QT autograft recipients.

Study Design: Cohort study; Level of evidence, 3.

Methods: A single-center retrospective chart review was conducted between January 2010 and November 2022. Skeletally mature patients who underwent primary ACLR with either QT or BTB autograft were considered for inclusion. Patients who received an alternate graft or those undergoing revision ACLR were excluded. The primary outcome of interest was return to the operating room for arthrofibrosis release (either manipulation under anesthesia or lysis of adhesions).

Results: Of 1726 included patients (1155 receiving a BTB autograft and 571 receiving a QT autograft), 5.2% (n = 60) of BTB recipients and 6.5% (n = 37) of QT recipients required subsequent arthrofibrosis. There was no significant association between graft type and subsequent arthrofibrosis ($P = .275$). There was a significant association with graft type and presence of a cyclops lesion (65.0% of BTB grafts and 40.5% of QT grafts; $P = .018$). After removing those patients with chronic tears who underwent ACLR at >1 year, patients who required arthrofibrosis were found to have a significantly shorter time between injury and ACLR (mean, 59.23 $\pm$ 48.46 days) than those who did not require arthrofibrosis (mean, 81.7 $\pm$ 72.63 days) ($P \leq .01$). Significantly more female patients (9.25%) than male patients (2.79%) required arthrofibrosis (hazard ratio, 3.82; $P < .001$), and patients who required arthrosis were significantly younger (mean, 22.52 $\pm$ 9.35 years) than those who did not (mean, 25.74 $\pm$ 10.83 years) ($P = .001$).

Conclusion: Study findings indicated no statistically significant difference in the rate of secondary arthrofibrosis surgery between patients who underwent ACLR with either QT or BTB autograft.

Keywords: knee ligaments; ACL; biomechanics of ligament; general sports trauma

Arthrofibrosis is a common complication after anterior cruciate ligament (ACL) reconstruction (ACLR), affecting anywhere from 2% to 35% of those undergoing primary ACLR.[8,15] Arthrofibrosis is a buildup of scar tissue around the knee and is clinically defined as a decrease in range of

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motion (ROM) compared with the contralateral knee.[8,15] The focal buildup of scar tissue at the anterior portion of the intercondylar space is defined as a cyclops lesion because of its arthroscopic appearance of a single horn or "cyclops eye." While a specific entity, a cyclops is a subset of generalized arthrofibrosis. Cyclops lesions occur in approximately 1.9% to 10% of ACLR recipients and can cause pain and reduced knee extension due to entrapment between the femur and tibia.[8,12] Many risk factors for arthrofibrosis and cyclops lesions have been identified. Risk factors may include female sex, younger age at time of surgery, reduced ROM, and significant knee inflammation at the time of ACLR.[5,7-8,12,15] Additional risks have been identified, including index injuries with bony avulsions and anatomic variants such as a narrow intercondylar notch. Intraoperative variables such as anterior positioning of the tibial graft tunnel, larger graft diameter, and concomitant procedures such as meniscal repair have also been cited.[5-8,12,15] While arthrofibrosis can often be treated nonoperatively, it can cause prolonged rehabilitation, delayed return to play, and decreased patient satisfaction, and may require additional invasive intervention.[15] If nonsurgical management fails, return to the operating room (OR) may be required for knee manipulation under anesthesia (MUA) or lysis of adhesions (LOA). Understanding modifiable risk factors for arthrofibrosis is important for improved patient outcomes.

Graft selection in ACLR is dependent on a host of factors, including the characteristics of the patient, their goals and expectations, the properties of the graft itself, healing, and donor site morbidity. Two of the more common autograft choices are quadriceps tendon (QT; with and without a patellar bone plug) and bone–patellar tendon–bone (BTB). QT grafts are slowly replacing the use of hamstring tendon autografts because of donor site morbidity, decreased postoperative laxity scores, and increased postoperative functional scores.[9,11] Some studies have not identified an increased risk for arthrofibrosis between BTB or hamstring tendon grafts.[13] In contrast, Huleatt et al[6] found an increased risk of a return to the OR for MUA or LOA with a QT graft compared with other graft types. While each individual graft has its own advantages and disadvantages, there has been some concern for increased overall revision rates for QT grafts when compared with BTB grafts,[10] although other studies have found equivalent survivorship between the graft types.[11]

To identify if graft choice between QT and BTB autograft was a risk factor for early return to the OR for arthrofibrosis, we conducted a single-institution retrospective chart review in the current study. We hypothesized that there would be an increased rate of return to the OR for arthrofibrosis release in the recipients of QT autografts.

METHODS

Study Design and Participants

After receiving institutional review board approval, we conducted a single-center retrospective chart review at our institution to identify patients who underwent a primary arthroscopically aided ACLR between January 1, 2010, and November 16, 2022. Patient data were collected by physicians and research staff and were obtained from the selected institution's electronic health records using a search of all patients with the Current Procedural Terminology (CPT) code for ACLR (29888).

Skeletally mature patients were included if they received either a QT or BTB autograft at their index procedure. Exclusion criteria included patients who were skeletally immature based on surgeon documentation, were treated for arthrofibrosis after a revision ACLR, had received an alternative graft (allograft or hamstring tendon autograft) at index ACLR, or had returned to the OR for a secondary procedure for reasons other than arthrofibrosis, extension loss, or cyclops lesion. Again, these patients were identified by chart review of operative notes.

Postoperative Stiffness After ACLR

To manage postoperative stiffness in patients after ACLR, a staged approach is utilized to standardize patient care. Initially, all patients undergo physical therapy focusing on passive extension exercises, active-assisted flexion and extension, and ROM exercises, including passive and active ROM. If patients do not achieve satisfactory improvement in ROM with physical therapy alone, MUA is performed. If the MUA procedure encounters considerable resistance, indicating that sufficient motion is not achieved, the clinical decision is made to proceed with an LOA procedure. Intraoperatively, if MUA provides adequate motion, LOA is not performed. For LOA, a standardized checklist is followed, which includes careful assessment of residual stiffness and targeted release of adhesions to maximize joint mobility. Postoperatively,

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TABLE 1
Arthrofibrosis Surgery Profile According to Graft Type[a]

Variable	QT Autograft (n = 571; 33%)	BTB Autograft (n = 1155; 67%)
Underwent arthrofibrosis (n = 97)	37 (38.1)[b]	60 (61.9)[b]
MUA (n = 10)	1 (10)	9 (90)
LOA (n = 87)	36 (41.4)	51 (58.6)
Cyclops lesion present at arthrofibrosis	15/37 (40.5)	39/60 (65.0)

[a]Data are reported as No. of patients (%). BTB, bone–patellar tendon–bone; LOA, lysis of adhesions; MUA, manipulation under anesthesia; QT, quadriceps tendon.
[b]The rate of patients within each group who underwent arthrofibrosis was 6.5% (37/571) for QT autograft recipients and 5.2% (60/1155) for BTB autograft recipients.

patients receive a regimen of splinting as well as continued physical therapy aimed at achieving full extension and improving flexion.

Outcome Measures

The primary outcome of interest was whether graft choice at index ACLR, either QT or BTB autograft, was associated with increased rates of return to the OR for arthrofibrosis release (MUA [CPT code 27570] or LOA [CPT code 29884]). Variables including patient characteristics (age, sex, and body mass index [BMI]) were collected, as well as time from injury to index ACLR, graft type, and dates of all procedures. Graft type and additional procedure performed were identified by chart review of the operative notes of each patient. QT grafts were not stratified according to all soft tissue versus patellar bone plug or full versus partial thickness. Additional procedures at time of the index ACLR were reviewed and documented as either "yes" or "no," with specifics as to type of procedure not documented.

Statistical Analysis

Data were reported as means with standard deviations and as counts with percentages. Data analysis was conducted using independent-samples tests, specifically the Levene test for equality of variances and *t* tests for equality of means, to analyze the time from injury to ACLR between patients who underwent surgery at 3 weeks, 6 weeks, and 90 days from the date of injury. A binary logistic regression was performed with arthrofibrosis surgery as the dependent variable and age and graft type as the independent variables. Cross-tabulation and chi-square analyses were utilized to assess the significance of associations between graft type and return to the OR for arthrofibrosis release, graft type and type of arthrofibrosis (MUA vs LOA), graft type and presence of a cyclops lesion, patient sex and return to the OR, and graft type and sex in patients returning for arthrofibrosis. Additionally, we used *t* tests to compare patient age and time between injury and surgery between patients who required an arthrofibrosis release and those who did not.

RESULTS

The number of ACLR procedures identified from the electronic health records was 3683. Of these patients, 1726 (571 receiving a QT autograft and 1155 receiving a BTB autograft) met inclusion criteria by chart review. There were 97 patients (QT: 37 [6.5%]; BTB: 60 [5.2%]) who returned to the OR for MUA or LOA. Of the 60 patients with BTB grafts who required an arthrofibrosis release, 39 (65%) had a noted cyclops lesion, compared with 15 of the 37 (40.5%) QT recipients (Table 1).

Within patients who underwent arthrofibrosis, there was no significant difference between graft types (QT vs BTB: 6.5% vs 5.2%; $P = .275$), nor was there a significant association between graft type and type of arthrofibrosis, MUA or LOA ($P = .053$) (Table 2). There was a significant association between graft type and presence of a documented cyclops lesion ($P = .018$).

On average, those who required an arthrofibrosis release had a shorter time interval between their injury date and index ACLR than those who did not require a return to the OR (74.48 ± 103 vs 247.11 ± 623.40 days; $P \leq .01$). This difference remained significant even when removing those patients with chronic tears who underwent ACLR >1 year from their date of injury (arthrofibrosis vs no arthrofibrosis: 59.23 ± 48.46 vs 81.7 ± 72.63 days; $P \leq .01$). However, when looking at patients who had their index surgeries at or within 3 weeks, 6 weeks, or 90 days from their date of injury, the data were no longer statistically significant ($P = .254$, .061, and .36, respectively) (Table 2). There was no significant association in patients who required arthrofibrosis between those who had additional procedures performed at the time of index ACLR (72/1230; 5.9%) and those who underwent ACLR only (25/496; 5.0%) ($P = .507$).

When looking at all-comers, QT recipients returned to the OR for arthrofibrosis release significantly earlier (267.35 ± 168.52 days after ACLR) than BTB recipients (475.55 ± 629.31 days after ACLR) ($P = .009$). When removing patients who returned for an MUA or LOA at >1 year postoperatively, this difference became nonsignificant, with QT recipients returning a mean of 182.63 ± 64.11 days from ACLR and BTB recipients returning at 149.97 ± 89.95 days ($P = .053$) (Table 2).

TABLE 2
Comparison of Patient and Surgery Characteristics According to Subsequent Arthrofibrosis and Graft Type at Arthrofibrosis[a]

Variable	No Arthrofibrosis (n = 1629; 94.4%)	Arthrofibrosis (n = 97; 5.6%)	*P*
Sex			**≤.01**
Male	942 (57.8)	27 (27.8)	
Female	687 (42.2)	70 (72.2)	
Graft type			.275
QT	1095 (67.2)	60 (61.9)	
BTB	534 (32.8)	37 (38.1)	
BMI	24.86 ± 4.35	24.25 ± 4.56	.093
Age, y	25.74 ± 10.83	22.52 ± 9.35	**.001**
Time from injury to surgery, days			
All patients	247.11 ± 623.40	74.48 ± 103	**≤.01**
Surgery in ≤1 y (n = 1489)	81.7 ± 72.63 (n =1395)	59.23 ± 48.46 (n = 94)	**≤.01**
Surgery in ≤90 days (n = 1066)	43.93 ± 20.98 (n = 988)	43.05 ± 19.54 (n = 78)	.36
Surgery in ≤6 wk (n = 562)	26.92 ± 9.23 (n = 518)	29.18 ± 9.82 (n = 44)	.061
Surgery in ≤3 wk (n = 168)	15.64 ± 4.38 (n = 158)	14.70 ± 3.59 (n = 10)	.254
Additional procedures			.507
≥1 additional procedures	1158 (71.1)	72 (74.2)	
ACLR only	471 (28.9)	25 (25.8)	
	QT Autograft (n = 37)	BTB Autograft (n = 60)	
Time from ACLR to arthrofibrosis, days			
Any time after ACLR	267.35 ± 168.52	475.55 ± 629.31	**.009**
<1 y from ACLR (n = 60)	182.63 ± 64.11 (n = 27)	149.97 ± 89.95 (n = 33)	.053
Type of arthrofibrosis			.053
MUA	1 (2.7)	9 (15.0)	
LOA	36 (97.3)	51 (85.0)	
Cyclops lesion present at arthrofibrosis	15 (40.5)	39 (65.0)	**.018**

[a]Data are presented as No. of patients (%) or mean ± SD. Boldface *P* values indicate a statistically significant difference between groups ($P < .05$). ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; BTB, bone–patellar tendon–bone; LOA, lysis of adhesions; MUA, manipulation under anesthesia; QT, quadriceps tendon.

Overall, significantly more female patients (70/757; 9.25%) required a return to the OR for arthrofibrosis release than male patients (27/969; 2.79%) ($P \leq .01$). Female patients had a 3.5-fold higher likelihood of returning to the OR for MUA or LOA than male patients (hazard ratio, 3.82). After analyzing the graft type, there was no significant association with the type of arthrofibrosis performed (MUA vs LOA), although the association approached significance ($P = .053$). Specifically, of the patients receiving a BTB autograft requiring a return to the OR, 15% achieved sufficient ROM after MUA, whereas only 2.7% of patients receiving a QT autograft achieved sufficient ROM. This suggests that MUA may be more effective for patients receiving a BTB autograft in achieving desired motion compared with patients receiving a QT autograft, highlighting the importance of consistent postoperative management tactics.

Of the 60 patients who received a BTB graft and required an MUA or LOA, 47 (78.3%) were female and 13 (21.7%) were male. Among the 37 patients who received a QT graft and underwent a subsequent arthrofibrosis procedure, 23 (62.2%) were female and 14 (37.8%) were male. However, when analyzing the sex-based differences within each graft type, there was no significant difference between male and female patients returning for a subsequent arthrofibrosis procedure ($P = .85$), indicating that the overall effect of patient sex may not be as pronounced within each specific graft category.

Patients who required a subsequent arthrofibrosis procedure were significantly younger than those who did not (22.5 ± 9.4 vs 25.7 ± 10.9 years, respectively; $P = .001$). A binary logistic regression model using secondary arthrofibrosis surgery as the dependent variable, with age and graft type as independent variables, was statistically significant overall ($P = .003$). This indicates that the combination of age and graft type is significantly associated with the likelihood of arthrofibrosis. However, when the predictor "graft type" was assessed individually, it was not statistically significant ($P = .217$).

DISCUSSION

Of a total of 1155 BTB autograft and 571 QT autograft ACLR procedures identified, 60 (6.5%) BTB recipients

and 37 (5.2%) QT recipients were documented to have subsequently undergone arthrofibrosis release procedures. There was no significant association found between graft type (BTB or QT) and rate of return to the OR for arthrofibrosis (P = .27).

This study aimed to identify if the risk of returning to the OR for arthrofibrosis release, either MUA or arthroscopic LOA, was affected by the type of graft at index ACLR, either QT or BTB autograft. Although most surgeons at the selected institution prefer QT grafts as their primary graft, it was hypothesized that there would be an increased rate of return to the OR for arthrofibrosis for patients receiving a QT autograft. We speculated that these grafts would pose a greater risk because of the consistently large size of the graft, despite patient size or sex.[9,15] Retrospective analysis was completed with an approximately 13-year interval of patient data at the selected high-volume institution to assess the outcomes. The surgical data collected on patients overlapped by a 2-year interval. During this interval, the QT graft became more utilized than the BTB graft, representing a possible confounding variable.

The performed literature search did not identify any other studies comparing these 2 grafts in terms of arthrofibrosis. Surprisingly, it was found that there was a significant association with graft type and documented cyclops lesions. Patients who required an arthrofibrosis release after receiving a BTB graft had a higher percentage of a cyclops lesion than those who received a QT graft.

It has been theorized that cyclops lesions may develop because of inflammation at the ACL stump at the time of injury,[8] but perhaps the incorporation of the tibial bone plug may lead to an enhanced inflammatory or hypertrophic response. Although interesting, the clinical significance of this finding is yet unknown as it did not result in an overall increased rate of return to the OR for arthrofibrosis.

It has been demonstrated previously that performing a reconstruction too early after injury can lead to increased stiffness and rates of arthrofibrosis. Some studies cite 3 weeks[14] as the minimum critical time to wait, while others cite 4 weeks.[8] Most agree that the exact number of days after injury is less important than the resolution of the effusion/edema from the injury and return of ROM and QT strength.[2,8,10,15] It has been shown that this time can vary between patients and be impacted by the severity of injury and concomitant injuries such as bone bruising.[4] It was found that, overall, those who returned to the OR had a shorter time interval between their injury and index ACLR, which aligns with prior literature. This remained significant when those with chronic tears who underwent surgery >1 year from injury were excluded. Interestingly, there was no longer a significant association with time when there was further stratification of the interval between injury and surgery to within 3 weeks, 6 weeks, or 3 months. Within those criteria, the only interval that approached significance was the group who had surgery within 6 weeks of their injury (P = .06).

Other studies have cited female sex and younger age with larger graft size as risk factors for arthrofibrosis.[7,12,15] In this study, significantly more female than male patients required arthrofibrosis release and those who returned to the OR were younger on average. The reason for this increased risk is not entirely understood. It may be related to altered kinematics due to overstuffing a smaller native tibial footprint, or increased risk of impingement and scar formation due to anatomic variants such as notch width.[8,15] Facchetti et al[3] found that those with a cyclops lesion had a lower BMI than those without. In this study, BMI was not significantly associated with return to the OR for MUA or LOA. It is important to note that the mean BMI in both populations was within the healthy range (<24.9) as defined by the US Centers for Disease Control and Prevention.[1] Given that many ACLRs are performed in young, healthy athletes, this finding may not be generalizable to all patient populations.

This study did not find a statistically significant increase in arthrofibrosis release rate in those undergoing concomitant procedures with their ACLR compared with those without a concomitant procedure. This finding has been variable in other studies.[15] Alternate results may have been identified had those concomitant procedures been further stratified and analyzed by type.

Although there was no significant association between graft type and type of surgery performed (MUA vs LOA), it is interesting that the association approached significance with a P value of .053. Of the patients receiving a BTB autograft requiring return to the OR, 15% acquired sufficient ROM after manipulation, whereas only 2.7% patients receiving a QT autograft acquired sufficient ROM after manipulation.

Limitations

A limitation of this study was its retrospective design. Although it was conducted at a single institution, the chart review included patients from an approximately 13-year interval and included the patients of several surgeons. The differences in surgical technique, practice evolution over time (ie, change in frequency of primary graft used, improvement in surgical technique, etc), postoperative protocols, and physical therapy providers could not be controlled for. It is possible the results are subject to confounding, as this was a multisurgeon study, and although all surgeons agreed that adequate ROM and a resolution of swelling was required before surgery, the criteria for "adequate" may have differed between surgeon and over time within each practice. Another limitation includes not identifying or controlling concomitant procedures, which themselves could result in decreased postoperative knee motion or increased scarring, and no minimum follow-up was required.

As a single-institution study, patients may have been lost to follow-up at other institutions and a return to the OR for arthrofibrosis may not have been captured. Additionally, patients were treated for arthrofibrosis at the selected institution who had index procedures performed elsewhere. Another limitation was that we included all

QT grafts and did not stratify by full and partial thickness, or with and without bone graft. Finally, although an analysis demonstrated that this study was adequately powered and there were more than twice as many BTB recipients included in the study than QT recipients, a future analysis with more equivalent sample sizes may be performed as more QT grafts are utilized in general.

CONCLUSION

The study findings demonstrated that recipients of QT grafts in ACLR were not significantly more likely to return to the OR for arthrofibrosis release than those who received BTB grafts. When choosing a graft and counseling a patient, understanding modifiable risk factors may lead to better outcomes after ACLR.

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