



# Most Patients Report Acceptable Knee Function, Satisfaction, and Clinical Outcomes at a Minimum Ten Years After Quadriceps Free Tendon Anterior Cruciate Ligament Reconstruction

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**Purpose:** To describe the long-term outcomes of anterior cruciate ligament reconstruction (ACLR) with quadriceps-free tendon autograft (QFT) in terms of subjective function, clinical outcomes, and knee satisfaction. **Methods:** A retrospective chart review design with prospective descriptive survey was used to determine clinical and subjective outcomes for patients treated with a QFT-ACLR from 2000 to 2013. Patients with multiligament reconstructions were excluded. The primary outcomes were clinical outcomes (reinjury of indexed knee, ACL injury to contralateral knee after indexed surgery), subjective function (International Knee Documentation Committee subjective score, Lysholm score), knee satisfaction (single assessment numeric evaluation), and global health and wellbeing (Patient-Reported Outcomes Measurement Information System Global-10). **Results:** In total, 34 patients were contacted (average: 18.2 years, range: 10-23 years) after surgery (response rate, 17.3%). The mean age at time of surgery was  $32.3 \pm 11.1$  years, and  $50.4 \pm 11.6$  years at follow-up. For clinical outcomes, 23.5% of patients reported a reinjury of their QFT reconstructed ACL. Contralateral ACL injuries were reported in 17.6% of patients. No differences in subjective function and knee satisfaction were identified between patients with and without concomitant procedure at the time of surgery. Nearly two-thirds of patients reported strong mental health and physical function on the PROMIS Global Health. **Conclusions:** This study presents a minimum of 10-year follow-up on QFT-ACLR, revealing 74% of patients reporting no reinjury, 67% of patients reporting acceptable-exceptional subjective knee function, and 74% indicating better physical and mental health compared to the general population. No differences were observed in knee function or satisfaction scores among patients who underwent a concomitant cartilage procedure at the time of QFT-ACLR with patients without these concomitant injuries. **Level of Evidence:** Level IV, therapeutic case-series.

The anterior cruciate ligament (ACL) is the most injured ligament in the knee,<sup>1</sup> leading to substantial joint instability and potential meniscal and chondral damage. Reconstruction of the anterior cruciate ligament (ACLR) is the recommended treatment

for restoring joint stability. Surgeons have several graft choices for ACLR, including bone–patella tendon–bone (BPTB), hamstring tendon (HT), and more recently, quadriceps tendon (QT). The choice of graft depends on patient demographics, physical activity expectations, and surgeon preference and training.<sup>2</sup>

QT autografts have gained attention as a viable alternative to traditional BPTB and HT autografts.<sup>3</sup> Initially described by Marshall et al.<sup>4</sup> in 1979, QT grafts are noted for their advantageous biomechanical properties of collagen ratio<sup>5</sup> and thicker cross-sectional area.<sup>6</sup> Fulkerson et al.<sup>7,8</sup> later described quadriceps tendon without bone as a free tendon (QFT) graft, allowing for the extensor mechanism to remain intact,<sup>9,10</sup> preserving the function of the medial hamstrings,<sup>11,12</sup> and eliminating the risk of an iatrogenic patella fracture.<sup>13</sup> Current techniques still use QFT autograft as first described by Fulkerson in 1998.

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A substantial body of literature has been amassed on ACL injuries.<sup>14,15</sup> Early- to midterm studies on QT autografts suggest lower rates of anterior knee pain,<sup>16-19</sup> numbness,<sup>20</sup> and loss of extension<sup>20</sup> than BPTB grafts, with failure rates at 2 years being comparable<sup>19,20</sup> or lower.<sup>16</sup> However, conflicting reports on subjective function and satisfaction highlight a gap in understanding the long-term outcomes of QFT autografts.<sup>16,17,19</sup> Investigations from Germany<sup>21</sup> and South Korea<sup>22</sup> have shown satisfactory results using QT-patellar bone autografts. However, there is a notable scarcity of long-term studies on QT autografts, especially QFT autografts, in broader populations. Therefore, the purpose of this study was to describe the long-term outcomes of ACLR with QFT autograft (QFT-ACLR) in terms of subjective function, clinical outcomes, and knee satisfaction. We hypothesized that patients would report high satisfaction and acceptable clinical and surgical outcomes after QFT-ACLR.

## Methods

### Participants

This study used a retrospective chart review design with a prospective descriptive survey to determine clinical and subjective outcomes for patients treated for an ACL tear with a QFT-ACLR between January 2000 and March 2013. Institutional review board approval was obtained before initiation of this study. Case logs and billing information for a single surgeon (J.P.F.) were reviewed using Current Procedural Terminology code 29888 (Arthroscopically aided anterior cruciate ligament repair/augmentation or reconstruction). Medical recorded and operative reports of identified patients were then reviewed to confirm reconstruction with a QFT graft for patients between 15 and 50 years of age at the time of surgery. Patients with a multi-ligament reconstruction were excluded.

### Surgical Technique and Rehabilitation

All procedures were performed by a single surgeon (J.F.) under general anesthesia with a regional block. The surgical technique described originally by Fulkerson et al.<sup>7,8,14</sup> and later adopted by Slone et al.<sup>23</sup> was used for all patients. The QFT graft was harvested, with the knee flexed 90°, through a short longitudinal incision above the patella and extended about 2 inches proximally<sup>24</sup> using a No. 10 scalpel blade. Two parallel longitudinal incisions were made, approximately 9 mm apart and extending 8 cm proximally and 7 mm deep, partial thickness into the tendon (Fig 1). A graft with these dimensions was harvested, using blunt and sharp dissection after placing two #2 whipstitches in the distal end for tension during the harvest.

After or concomitantly by a second surgeon, standard anterolateral and anteromedial arthroscopy portals

were created. Diagnostic arthroscopy was performed and any concomitant pathology that was identified was treated accordingly. After drilling the 8-mm tibial tunnel, an 8-mm femoral socket was drilled using the transtibial technique in this early series. The sutures were placed through the central eyes of an endobutton, tying the knot at distal end of the tendon after measuring the socket length and assuring 2 to 2.5 cm of tendon in the socket (Fig 2). After deploying the endobutton and cycling the knee, a soft-tissue screw was used for fixation in the tibial tunnel.

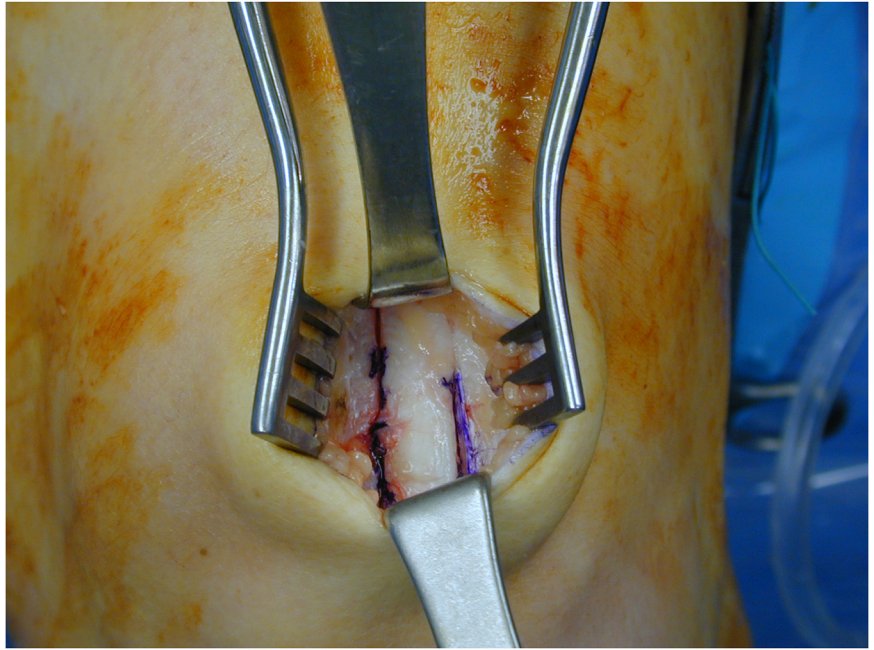
### Rehabilitation

Patients in this time frame were placed in knee immobilizers postoperatively, allowing immediate weight-bearing as tolerated on crutches. The immobilizer was removed liberally to work on full passive extension and closed chain strengthening started early with a goal of early full motion restoration. The immobilizer was generally discontinued by 6 weeks with formal physical therapy initiated soon after surgery with steady progression to full active and passive range of motion by 6 weeks postoperatively. Straight-ahead running was permitted at 4 months with full return to sports by 6 to 8 months.<sup>25</sup>

### Study Follow-Up

Patients with a confirmed QFT-ACLR, using the surgical technique previously described, were contacted by a member of the research team via telephone to explain the purpose of the study and obtain verbal informed consent. Patients who were contacted were screened for any nonorthopaedic impairment that could impact mobility and study results. Those who chose to participate in the study were sent a web link to complete a battery of questions via REDCap. This battery of questions served as the primary outcome for this study and included clinical outcomes, subjective function, knee satisfaction, and global health and well-being. Clinical outcomes were assessed by asking patients to self-report subsequent ACL graft failure and the need for revision ACLR surgery or addition surgery on the indexed knee (i.e., meniscectomies, total joint arthroplasty) along with ACL injury and surgical procedures on the contralateral knee after the indexed surgery. Subjective function was assessed using 2 validated questionnaires, the International Knee Documentation Committee (IKDC) subjective score<sup>26</sup> and Lysholm score.<sup>27</sup> Using normative data, a patient's IKDC subjective score can be converted to a standard z score to allow for comparison with a population mean on the basis of their age and sex.<sup>28</sup> Interpretation of Lysholm scores are considered exceptional (score: 100-95), acceptable (score: 94-84), fair (score: 83-65), and poor (score: 64 or lower).<sup>26</sup> To adjust for potential factors related to global health and well-being, and allow for this study's findings to be

**Fig 1.** In this series, grafts were harvested through a short longitudinal incision under direct vision to assure full graft integrity for reconstruction.

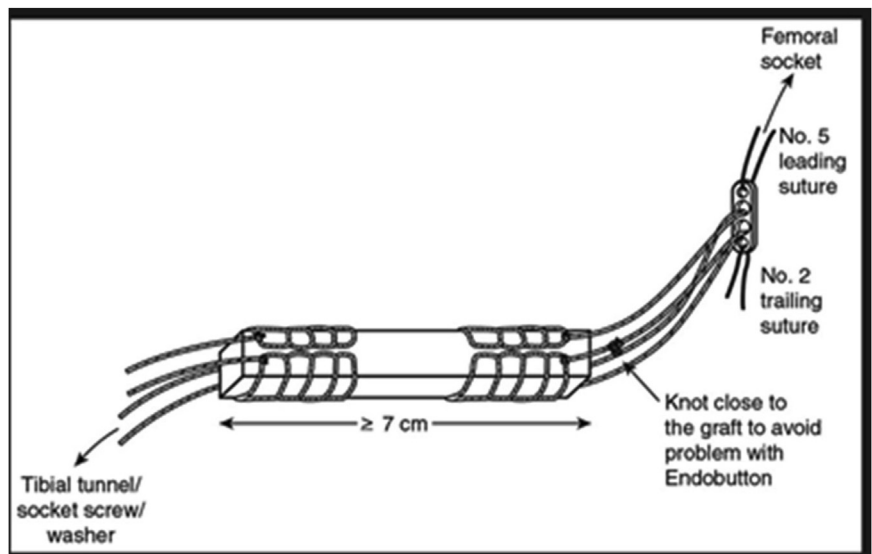


compared with other outcomes research,<sup>29</sup> participants also completed the Patient-Reported Outcomes Measurement Information System (PROMIS) Global-10. PROMIS scores were reported as *t* scores, whereas a score less than 40 is 1 standard deviation below the national benchmark (at risk for poor mental health or poor physical function), and greater than 60 is 1 standard deviation about the national benchmark. Knee satisfaction was measured using the single assessment numeric evaluation (SANE).<sup>30</sup> This is a single question that asks patients, "If I had to give my knee a grade

from 1 to 100, with 100 being the best, I would give my knee a \_\_\_\_."

Given the descriptive nature of this study and a sample of convenience, a power analysis was not calculated. Data for clinical outcomes, subjective function, and satisfaction are portrayed using general descriptive statistics. For continuous data, histograms were used to determine whether parametric assumptions of normality were met. Parametric, continuous data are presented as means and standard deviations. Nonparametric, continuous data are presented as

**Fig 2.** Surgical preparation of a quadriceps free tendon autograft. (Reprinted with permission from Busam ML, Fulkerson JP, Gaskill TR, Moorman III CT, Noyes FR, Galloway MT: Technical Aspects of Anterior Cruciate Ligament Reconstruction for the General Orthopaedic Surgeon. AAOS Instr Course Lect 2011;60:485-497.)

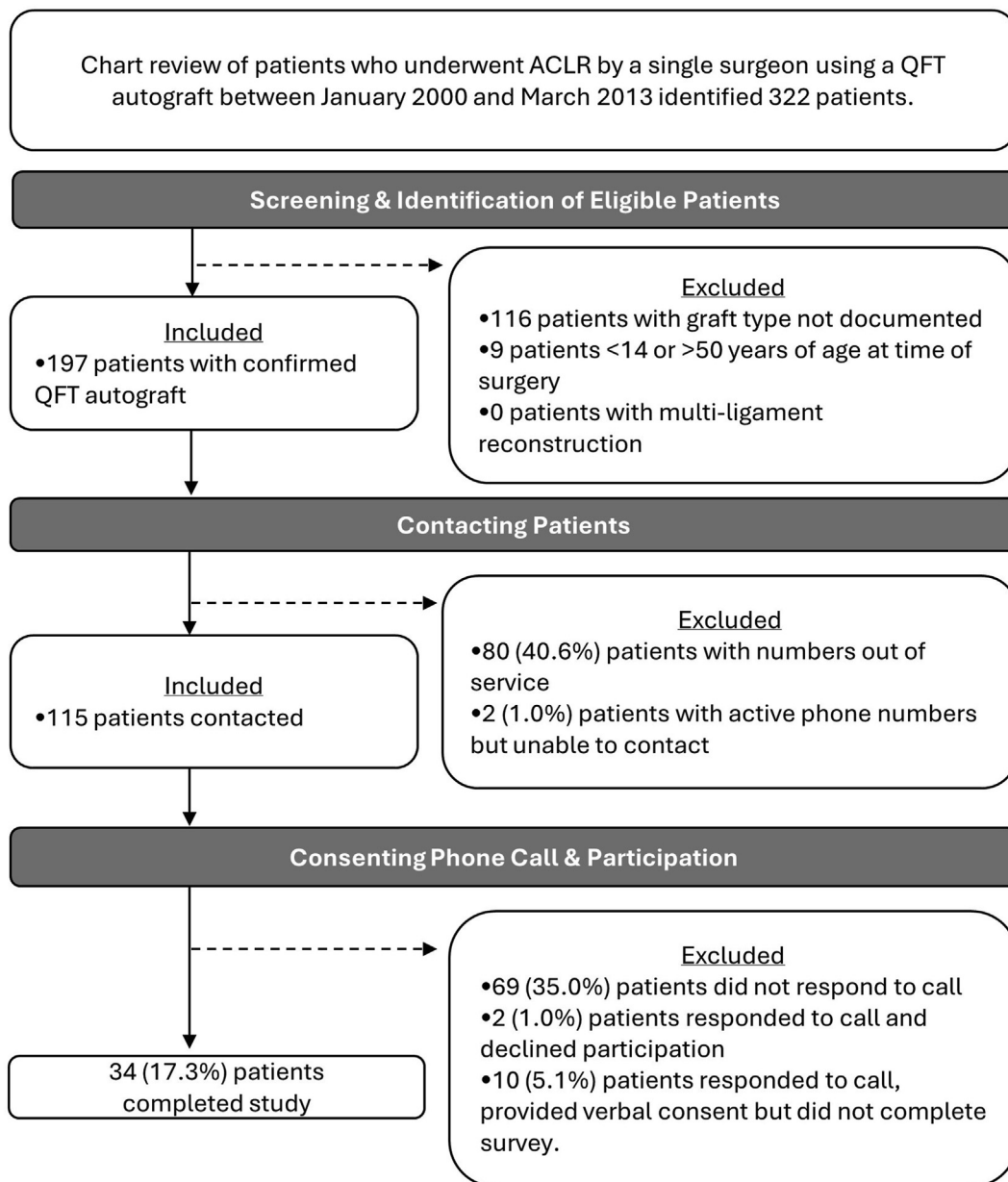


median and interquartile range. Categorical data are presented as counts, proportions, and percentages. Differences in patient demographics among patients contacted and those unable to contact, along with differences in patient-reported outcomes among patients with and without concomitant procedures, were assessed using univariate testing (Student *t* tests,  $\chi^2$  test, and Fisher exact test). Data were stratified by patients with and without concomitant pathology at time of surgery for clinical relevance. Data were analyzed using STATA (StataCorp. 2021; Stata Statistical Software: Release 17, StataCorp LLC, College Station, TX).

## Results

In total, 197 patients were identified with a QFT-ACLR (Fig 3). A total of 34 patients completed the study, for a response rate of 17.3%. Patients who were contacted were older at time of surgery compared with patients who were not contacted. No other differences were found between these 2 groups for sex, laterality, or concomitant procedures completed during QT ACLR (Table 1).

The average length of time between surgery and completion of the study battery of questions was 18.2 years (range: 10-23 years). Patient demographics are



**Fig 3.** Flow chart of excluded and included patients. (ACLR, anterior cruciate ligament reconstruction; QFT, quadriceps tendon without bone as a free tendon.)



**Table 1.** Exploring Whether Differences Exist Between Patients Contacted and Those Who Were Not Contacted

|                                  | Contacted<br>n = 42 | Not Contacted<br>n = 133 | P Value |
|----------------------------------|---------------------|--------------------------|---------|
| Age at surgery, yr               | 32.1 ± 11.6         | 27.1 ± 11.1              | .010    |
| Sex                              |                     |                          |         |
| Male                             | 24 (60.9)           | 85 (56.7)                | .614    |
| Female                           | 18 (39.1)           | 48 (43.3)                |         |
| Concomitant procedure at surgery |                     |                          |         |
| None                             | 32 (69.6)           | 105 (72.4)               | .684    |
| Meniscal repair                  | 3 (6.5)             | 10 (6.9)                 |         |
| Meniscectomy                     | 8 (17.4)            | 27 (18.6)                |         |
| Chondroplasty                    | 1 (2.1)             | 1 (0.7)                  |         |
| Other                            | 2 (4.4)             | 2 (1.4)                  |         |
| Laterality                       |                     |                          |         |
| Right                            | 24 (52.2)           | 67 (48.6)                | .670    |
| Left                             | 22 (47.8)           | 71 (51.5)                |         |

NOTE. Age is reported as mean ± standard deviation, and count (percentage) is used for all other values.

displayed in Table 2. When assessing reinjury to the QFT graft, 73.5% of patients (n = 25) reported no reinjury, 23.5% (n = 8) reported another ACL injury, and 3.0% (n = 1) were unsure whether reinjury had occurred. Of the 23.5% of patients who reported reinjury of their indexed reconstructed knee, 62.5% (n = 5) were male and 37.5% (n = 3) were female. Results of the Fisher exact test did not identify distribution differences in injury rates by sex ( $P = .661$ ). One half of the patients (n = 4) who sustained a QFT graft injury had revision surgery, and 50% (n = 4) did not elect to have the ligament revised. Injury to the contralateral ACL after the indexed QFT-ACLR was reported in 17.6% (n = 6) of patients. When we assessed subsequent non-ACLR surgeries on the indexed QFT-ACLR knee, 67.6% (n = 23) of patients reported no additional surgeries compared with 32.4% (n = 11) who reported additional surgeries. These additional surgeries included meniscectomy (6%, n = 2), debridement (3%, n = 1), loose body removal (3%, n = 1), and knee replacement (3%, n = 1). There were 2 patients who

were unsure of the type of subsequent surgical procedure they had on their knee.

Patient-reported outcome scores from all 34 patients are presented in Table 3. On average, patients reported acceptable Lysholm scores. When stratifying by scoring classification, 41% (n = 14) of patients had exceptional scores, 26% (n = 9) had acceptable scores, 21% (n = 7) had fair scores, and 12% (n = 4) had poor scores. After standardizing IKDC scores on the basis of current age and sex, the average z score was 0.10 (range: -1.65 to 1.12), indicating patients who underwent QFT-ACLR reported a z score 0.10 of a standard deviation above the population mean. There were 68 (n = 23) of patients with a positive z score compared with 32% (n = 11) of patients with a negative z score. Most patients (73.5%) reported a PROMIS t score of 1 standard deviation greater than the general population on both the mental health and physical health subsections. There were 35% (n = 12) of patients who had a concomitant surgical procedure at the time of QFT-ACLR. No differences were identified in IKDC ( $P = .859$ ), Lysholm ( $P = .866$ ), or SANE ( $P = .920$ ) scores between patient with concomitant procedures and those with no additional procedure at time of QFT-ACLR. Further stratification of PRO scores based on subsequent ACL injury of the indexed knee and subsequent non-ACL surgery are presented in Table 4. This subanalysis revealed patients who experienced a subsequent ACL injury reported lower Lysholm scores compared with patients who did not reinjury the ACL in their indexed knee ( $P = .019$ ), with IKDC ( $P = .054$ ) and SANE ( $P = .049$ ) scores trending to show a difference between groups.

**Table 2.** Demographics of the Study Sample (n = 34)

|                        |              |
|------------------------|--------------|
| Age at surgery, yr     | 32.3 (15-52) |
| Age at follow-up, yr   | 52.4 (32-70) |
| Sex                    |              |
| Male                   | 20 (58.8%)   |
| Female                 | 14 (41.2%)   |
| Concomitant procedures |              |
| None                   | 22 (64.7%)   |
| Meniscal repair        | 2 (5.9%)     |
| Meniscectomy           | 7 (20.6%)    |
| Chondroplasty          | 1 (3.0%)     |
| Other                  | 2 (5.9%)     |
| Laterality             |              |
| Right                  | 16 (47.1%)   |
| Left                   | 18 (52.9%)   |

NOTE. Age is reported as mean ± standard deviation, and count (percentage) is used for all other values.

## Discussion

The most important finding of this study was that, on average, patients reported acceptable knee function and satisfaction a decade after surgery. In addition, most

**Table 3.** Patient-Reported Outcomes, Stratified by Presence of Concomitant Procedure

|                           | Total Sample<br>N = 34 | No Concomitant Procedure<br>n = 22 | Concomitant Procedure<br>n = 12 | P Value |
|---------------------------|------------------------|------------------------------------|---------------------------------|---------|
| IKDC                      | 81.7 (39.1-100)        | 82.2 (42.5-100)                    | 81.0 (39.1-100)                 | .859    |
| Lysholm                   | 85.5 (41.0-100)        | 85.8 (59.0-100)                    | 84.8 (41.0-100)                 | .866    |
| SANE                      | 81.2 (20.0-100)        | 80.9 (20.0-100)                    | 81.7 (24.0-100)                 | .920    |
| PROMIS Global Health      |                        |                                    |                                 |         |
| Mental Health T-Score     |                        |                                    |                                 |         |
| 40-50                     | 9 (26.5%)              | 7 (31.8%)                          | 2 (16.7%)                       | —       |
| >50                       | 25 (73.5%)             | 15 (68.2%)                         | 10 (83.3%)                      |         |
| Physical Function T-Score |                        |                                    |                                 |         |
| <40                       | 2 (5.9%)               | 2 (9.1%)                           | 0 (0.0%)                        | —       |
| 40-50                     | 7 (20.6%)              | 5 (22.7%)                          | 2 (16.7%)                       |         |
| >50                       | 25 (73.5%)             | 15 (68.2%)                         | 10 (83.4%)                      |         |

NOTE. IKDC, Lysholm, and SANE results are reported as mean (range). PROMIS Global Health results are reported as counts (percentage). IKDC, International Knee Documentation Committee, Subjective Knee Evaluation Form; SANE, Single Assessment Numeric Evaluation.

patients reported global physical and mental health scores greater than the U.S. population.

Graft failure and contralateral ACL injuries continues to be a notable adverse event after ACLR, regardless of graft type. In the immediate 2 years after reconstruction, graft failures from BPTB and HT autografts have been reported in 1.2% to 2.5% and 1.7% to 2.7% of cases, respectively,<sup>15,31</sup> with greater rates reported in specific subpopulations.<sup>32,33</sup> During this same time frame, QT graft failures have been reported in 0.7% of cases.<sup>15</sup> However, length of follow-up is a critical component for assessing failure risk. Our findings revealed a quarter of patients reported a subsequent ACL injury to their reconstructed knee during the 10 years after their initial surgery. This is a larger proportion compared with an ACL graft rupture rate of 1.8% to 10.4% for BPTB and HT autografts with a minimum of 5-year follow up reported by Wright et al.<sup>34</sup> The contralateral ACL is also at risk for injury, with injury as high as 19% within 1 year after return to sport.<sup>35</sup>

Patients younger than 20 years of age and those returning back to cutting or pivoting sports are at 3- to 5-fold risk of injuring their contralateral ACL when their ACL was reconstructed with an HT autograft.<sup>36</sup> Using the Kaiser Permanent ACLR registry,<sup>37</sup> authors found that crude rates for contralateral ACL injuries were greater after reconstruction using BPTB autograft compared with HS autografts. The omission of QT autografts highlights a gap in the current knowledge base. Despite a small study cohort, our finding of 18% of patients who sustain injury to the contralateral ACL after reconstruction using a QFT autograft begins to fill in this gap.

The inclusion of patient-reported outcomes allows for a patient-centered perspective on for efficacy of surgical intervention quality.<sup>38</sup> Using validated, legacy measures of physical function, the present study reported an average IKDC and Lysholm score of 81.7 and 85.5, respectively. Early follow-up after QFT-ACLR has demonstrated similar subjective outcomes to traditional

**Table 4.** Patient-Reported Outcomes, Stratified by Reinjury Status and Subsequent Non-ACL Surgeries

|                           | Subsequent Injury to QFT Graft |                        |         | Subsequent Non-ACLR surgeries |                              |         |
|---------------------------|--------------------------------|------------------------|---------|-------------------------------|------------------------------|---------|
|                           | None<br>n = 25                 | Injury to QFT<br>n = 8 | P Value | None<br>n = 23                | Additional Surgery<br>n = 11 | P Value |
| IKDC                      | 87.1 (47.1-100)                | 70.5 (42.5-94.3)       | .054    | 85.3 (47.1-100)               | 74.5 (39.1-98.9)             | .151    |
| Lysholm                   | 90.7 (65.0-100)                | 74.6 (59.0-95.0)       | .019    | 89.1 (65.0-100)               | 77.8 (41.0-100)              | .105    |
| SANE                      | 87.6 (55.0-100)                | 63.9 (20.0-95.0)       | .049    | 85.2 (24.0-100)               | 72.7 (20.0-100)              | .124    |
| PROMIS Global Health      |                                |                        |         |                               |                              |         |
| Mental Health T-Score     |                                |                        |         |                               |                              |         |
| 40-50                     | 5 (20.0%)                      | 3 (37.5%)              | —       | 5 (21.4%)                     | 4 (36.4%)                    | —       |
| >50                       | 20 (80.0%)                     | 5 (62.5%)              |         | 18 (78.3%)                    | 7 (63.6%)                    |         |
| Physical Function T-Score |                                |                        |         |                               |                              |         |
| <40                       | 1 (4.0%)                       | 1 (12.5%)              | —       | 1 (4.4%)                      | 1 (9.1%)                     | —       |
| 40-50                     | 3 (12.0%)                      | 4 (50.0%)              |         | 4 (17.4%)                     | 3 (27.3%)                    |         |
| >50                       | 21 (84.0%)                     | 3 (37.5%)              |         | 18 (78.3%)                    | 7 (63.6%)                    |         |

NOTE. The cohort consisted of 34 patients. There are only 33 patients in the subsequent injury to quadriceps free tendon (QFT); 1 patient was unsure of a recurrent injury and was not included in the stratification.

NOTE. IKDC, Lysholm, and SANE results are reported as mean (range). PROMIS Global Health results are reported as counts (percentage). IKDC, International Knee Documentation Committee, Subjective Knee Evaluation Form; SANE, Single Assessment Numeric Evaluation.

grafts. A randomized control trial assessing subjective outcomes between QT and HS autografts revealed no differences in IKDC scores between the 2 graft types.<sup>39</sup> Todor et al.<sup>40</sup> revealed an average Lysholm score of 89 for patients 2 years after QFT-ACLR, with no significant difference in scores when compared with patients treated with HS. At 6 years following after, Runer et al.<sup>41</sup> demonstrated similar findings with an average Lysholm score of 92 and IKDC score of 94 from patients with QT-ACLR. Our findings build on the current knowledge base by providing subjective scores of physical function from patients at least 10 years removed from QFT-ACLR. Further, our results are similar to mid- and long-term scores reported by patients with BPTB autografts.<sup>42,43</sup> However, it is important to consider the role of concomitant pathology at the time of reconstructive surgery on subjective outcomes, as injuries to the meniscus and chondral surface can negatively influence PROM scores.<sup>44</sup>

SANE scores have been shown to have a positive correlation with other PROMs<sup>45</sup> and a greater likelihood of returning to sport for patients who achieve greater scores. Although long-term SANE scores for patients undergoing ACLR are less understood, our PROMIS results indicate that patients generally report conditions above the mean for the general population in terms of mental health and physical function. PROMIS has been previously recognized as a valuable tool for assessing patient outcomes after ACLR, especially in identifying poorer outcomes.<sup>46</sup> This suggests that although SANE scores offer insight into physical recovery and sport return rates, PROMIS provides a broader view of mental health and overall well-being.

The findings of the current study are relevant to clinical application, particularly in the search for the optimal graft type in ACLR. Although the present study draws no direct comparison with other graft types, it does provide a long-term follow-up of patients who received QT autograft ACL surgery and report knee satisfaction and function at a level that is comparable with that in current literature for alternative graft types. This information can help guide surgeons and patients when considering the long-term implications of QFT ACLR compared with other grafts, with strong patient outcomes even in extended follow-up.

### Limitations

This study has several limitations that warrant consideration. First, the overall response rate for the study group was low. This may have confounded our data and skewed the results. In addition, we were not able to assess baseline physical capacity or the rate of return to play. Therefore, the results of our study cannot be used specifically to counsel patients regarding likelihood of returning to preinjury level of activity. We are unable to report the time from injury to clinical

presentation and surgery, which may have an association with concomitant injuries and subsequent failures. Rates of complications after surgery, such as infection or arthrofibrosis, were not obtained in this study. The presence of these complications may have influenced long-term outcomes. At follow-up, we do not have any physical examination data or radiographs for objective evaluation of each patient and therefore the data are strictly based upon perception of current condition and fails to provide insight into possible confounding variables in the early, mid- or late-term recovery after reconstruction. We have no baseline metrics from which to compare our results and therefore conclusions drawn from this study may be confounded by recall bias.

### Conclusions

This study presents a minimum of 10-year follow-up on QFT-ACLR, revealing 74% of patients reporting no reinjury, 67% of patients reporting acceptable to exceptional subjective knee function, and 74% indicating better physical and mental health compared with the general population. Further, no differences were observed in IKDC, Lysholm, or SANE scores among patients who underwent a concomitant cartilage procedure at the time of QFT-ALCR with patients without these concomitant injuries.

### Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: J.P.F. is President of the Patellofemoral Foundation. All other authors (C.H., R.K., M.E.S., C.G.R.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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