Long-term Outcomes of Anterior Cruciate Ligament Reconstruction Using Quadriceps Tendon–Patellar Bone Autograft

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**Background:** To date, there have been few studies on the outcomes of anterior cruciate ligament reconstruction (ACLR) using quadriceps tendon–patellar bone (QTPB) autograft.

**Purpose:** To evaluate the long-term clinical outcomes of ACLR using QTPB autograft.

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

**Methods:** We retrospectively reviewed 139 patients who underwent primary ACLR with QTPB autografts and had at least 7 years of postoperative follow-up data. Instability, clinical scores, donor-site morbidity, radiographic progression of osteoarthritis, and any associated complications were assessed.

**Results:** The proportion of knees classified as grade >1 on the anterior drawer, Lachman, and pivot-shift tests decreased significantly postsurgically (from 47.4% to 5.0%, 48.9% to 4.3%, and 53.3% to 5.0%, respectively; \( P < .001 \) for all). The mean clinical scores at the final follow-up were 89.8, 81.0, and 4.4 for the Lysholm, International Knee Documentation Committee, and Tegner Activity Scale, respectively. The results of the Cybex II dynamometer isokinetic test showed decreases in flexion and extension strength at both 60° and 180° per second, which persisted until the final follow-up visit. About one-fifth (19.4%) of the patients had osteoarthritis (Kellgren-Lawrence grade ≥1) before surgery, which increased to 33.8% at the final follow-up. The overall complication rate was 23.2%, and about one-third of the patients who experienced complications underwent revision surgery as a result of graft rupture and residual instability.

**Conclusion:** In the current study, ACLR using QTPB autograft provided satisfactory long-term clinical results, with acceptable rates of complication and donor-site morbidity.

**Keywords:** anterior cruciate ligament; anterior cruciate ligament reconstruction; quadriceps tendon–patellar bone; quadriceps tendon–patellar bone autograft

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Anterior cruciate ligament (ACL) ruptures are among the most common orthopaedic injuries, especially in young active patients, with approximately 30 to 40 reconstructions performed per 100,000 people.10 The incidence of ACL reconstruction (ACLR) is increasing as more people participate in sports while at the same time surgical techniques advance.11 Over the decades, many types of ACLR grafts have been studied, and the debate continues regarding optimal graft choice. The two most common and well-studied autografts used for ACLR are the bone–patellar tendon–bone (BPTB) graft and hamstring graft.15 Recently, quadriceps tendon (QT) and quadriceps tendon–patellar bone (QTPB) grafts have emerged as alternative graft choices with comparable function and complication rates.5,6,8 Despite growing evidence supporting QT and QTPB as excellent graft options in ACLR, in comparison with BPTB or hamstring grafts, they are seldom used,15 and there have been few studies on the outcomes of ACLR using QT or QTPB autografts.3

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Ethical approval for this study was obtained from Seoul National University Hospital (No. H-2006-023-113).
This study was performed to evaluate the long-term clinical results of ACLRs that used QTPB autografts. We postulated that the use of QTPB autografts in ACLR would result in equivalent long-term clinical outcomes to other well-studied graft choices (hamstring and BPTB).

METHODS

We received institutional review board approval for this retrospective study. From February 1999 to December 2012, 426 patients who underwent primary ACLR with QTPB autografts were screened. Patients who were followed up with for >7 years after ACLR were selected, and the exclusion criteria included previous knee surgery; previous ligamentous injury including chronic ACL tears; and concomitant meniscal or ligamentous injury of the affected knee (other than grade I or II medial collateral ligament injury). Ultimately, 139 patients were included in this study (Figure 1).

Surgical Technique

Both the harvesting and preparation of QTPB autografts were performed as described previously.7 A tibial tunnel 10 mm in diameter was drilled, and the intra-articular opening of the tunnel was aligned to the center of the ACL attachment. A 7-mm offset guide was inserted through the tibial tunnel for femoral tunnel placement. Midway through the study (April 2006), modifications to the conventional transtibial (TT) technique were implemented to achieve a more oblique, anatomic trajectory of the femoral tunnel. These modifications included sequential application of the anterior drawer, varus, and external rotation forces to the proximal tibia as well as external rotation of the previously inserted femoral guide. Finally, the drill guide was aimed at the lateral bifurcate ridge on the medial wall of the lateral femoral condyle. In total, 94 ACLRs performed using the TT technique in addition to 45 performed using the modified TT technique, were included in the study.

Rehabilitation Protocol

The postoperative rehabilitation protocol was uniform over the entire study period. Continuous passive motion was started with an assistive device within 2 days of surgery and continued for 1 to 2 days during the hospitalization period. A motion-control brace set at 0° to 90° was applied for 4 weeks. Full flexion was obtained within an additional 2 weeks. Patients were limited to partial weightbearing for 4 to 6 weeks and then progressed to full weightbearing as tolerated. Full sports activities such as jumping, running, and pivoting were allowed 6 months after surgery, once recovery of quadriceps muscle strength had been confirmed by physical examination in the clinic.

Clinical Evaluation

Clinical assessments were performed preoperatively, at 3 months and 1 year postoperatively, and annually thereafter. Clinical variables included instability, clinical scores, donor-site morbidity, radiographic progression of osteoarthritis, and any associated complications. Instability was evaluated via physical examinations (anterior drawer test, Lachman test, and pivot-shift test) and the KT-2000 arthrometer (MEDmetric). Physical examinations were performed in the outpatient clinic by an independent observer. The Lysholm, International Knee Documentation Committee (IKDC), and Tegner Activity Scale scores were obtained. Donor-site morbidity was determined via measurement of quadriceps strength using the Cybex II isokinetic dynamometer (CYBEX) at 60° and 180° per second and Shelbourne and Trumper anterior knee pain questionnaire.17 The Cybex II results were recorded as percentages relative to the contralateral (normal) side. Furthermore, as a measure of osteoarthritis progression, the Kellgren-Lawrence (K-L) grade at the final follow-up visit was obtained and confirmed by 2 experienced orthopaedic surgeons (S.J. and D.H.R.). Any complications, such as rerupture, residual instability, or cyclops lesion, were recorded in the electronic medical charts.

Statistical Analysis

Continuous variables are presented as means and standard deviations, and categorical variables are presented as frequencies and percentages. The demographics and preoperative clinical variables of the included patients were compared with those who were excluded from the study due to loss of follow-up (control group; n = 233). Continuous and categorical variables were compared using the independent t test and Fisher exact test, respectively. All statistical analyses were performed using SPSS Version 25.0.0 (SPSS). P < .05 indicated statistical significance.
TABLE 1

demographic Data of the Patients

| Study                  | Patients | Controls | P Value |
|------------------------|----------|----------|---------|
| No. of knees           | 139      | 233      |         |
| Age, y                 | 30.0 ± 6.5 | 31.0 ± 9.6 | .685    |
| Sex, male/female       | 119/20   | 248/25   | .108    |
| Side, right/left       | 75/64    | 143/130  | .762    |
| BMI, kg/cm²            | 25.1 ± 4.1 | 25.7 ± 3.4 | .782    |
| Follow-up length, y    | 10.2 ± 2.6 | 2.2 ± 1.9 | <.001   |
| Preoperative Tegner scale | 3.0 ± 1.8 | 3.5 ± 1.8 | .251    |
| Preoperative Lysholm score | 71.1 ± 12.6 | 68.2 ± 15.5 | .493    |

aData are reported as n or mean ± SD. Value in bold indicates statistically significant differences between groups (P < .05). BMI, body mass index.

TABLE 2

Evaluation of Knee Instability Before Surgery and at the Final Visit

|                      | Preoperative | Final Visit | P Value |
|----------------------|--------------|-------------|---------|
| Anterior drawer test |              |             | <.001   |
| Grade 0              | 14 (10.1)    | 86 (61.9)   |         |
| Grade 1              | 59 (42.4)    | 46 (33.1)   |         |
| Grade 2              | 54 (38.8)    | 7 (5.0)     |         |
| Grade 3              | 12 (8.6)     | 0 (0.0)     |         |
| Lachman test         |              |             | <.001   |
| Grade 0              | 12 (8.6)     | 84 (60.4)   |         |
| Grade 1              | 59 (42.4)    | 49 (35.3)   |         |
| Grade 2              | 54 (38.8)    | 6 (4.3)     |         |
| Grade 3              | 14 (10.1)    | 0 (0.0)     |         |
| Pivot-shift test     |              |             | <.001   |
| Grade 0              | 11 (7.9)     | 80 (57.6)   |         |
| Grade 1              | 54 (38.8)    | 52 (37.4)   |         |
| Grade 2              | 61 (43.9)    | 7 (5.0)     |         |
| Grade 3              | 13 (9.4)     | 0 (0.0)     |         |
| KT-2000              |              |             | <.001   |
| <3 mm                | 4.4 ± 2.0    | 2.1 ± 1.1   |         |
| 3-5 mm               | 22 (15.8)    | 100 (71.9)  |         |
| >5 mm                | 84 (60.4)    | 39 (28.1)   |         |

aData are reported as n (%) or mean ± SD. Values in bold indicate statistically significant differences (P < .05).

RESULTS

The demographics of the patients included in the study are shown in Table 1. The mean age on the day of surgery was 30.0 years, and the mean follow-up period was 10.2 years (range, 7-19 years). There was a clear male predominance, and the affected side was relatively evenly distributed (right side, 54.0%). The demographics and preoperative clinical scores (Tegner and Lysholm scores) were not significantly different between the study patients and the control group (excluded patients) except for the length of follow-up.

Significant improvements in knee stability were observed postsurgically, as determined by physical examination and arthrometry (Table 2). The proportion of knees classified as grade >1 on the anterior drawer, Lachman,

and pivot-shift tests decreased significantly after surgery (from 47.4% to 5.0%, 48.9% to 4.3%, and 53.3% to 5.0%, respectively; all P < .001). In the KT-2000 arthrometer, the overall side-to-side difference was <3 mm in 71.9% of the patients at the final follow-up.

The Cybex II dynamometer results showed decreases in flexion and extension strength at both 60° and 180° per second, which persisted until the final follow-up visit (Figure 2). Flexion strength was better preserved than extension strength throughout the follow-up period. The proportions of patients who complained of moderate to severe anterior knee pain in association with strenuous work/exercise, stair climbing, prolonged sitting, kneeling, and activities of daily living were 14.4%, 4.3%, 8.6%, 10.1%, and 5%, respectively. Donor-site tenderness was noted in 2.9% of the patients.

Clinical scores improved markedly after ACLR (Table 3). Although the clinical scores decreased slightly over time, 77.3% of the patients had a good to excellent Lysholm score at their final visit.

Complications are detailed in Table 4. Patients who were lost to follow-up before 7 years but had definite complications during the follow-up were included in the analysis (n = 16). The overall complication rate was 20.0%, and about one-third of the patients who experienced complications underwent revision surgery due to rerupture and residual instability. About one-fifth (19.4%) of the patients had osteoarthritis (K-L grade ≥1) before surgery, which increased to 33.8% at the final follow-up.

DISCUSSION

To our knowledge, to date, this is the largest study reporting the long-term clinical outcomes of ACLR using QT/QTPB autografts. The most important findings were that the QTPB autograft showed fair long-term clinical results. More than 90% of the patients had grade ≤1 knees based on all of the physical examinations (anterior drawer, Lachman, and pivot-shift tests).
The shorter follow-up period (mean, 10.2 years) in the present study may have accounted for the higher mean Lysholm score and percentage of good to excellent results compared with this previous study (89.8 and 77.3%, respectively). The proportion of patients with K-L grade ≥3 knees at the final evaluation in the previous study was 19%, which was much higher than in the present study (2.1%). However, the lower mean age of the patients in the present study (40.2 and 45.8 years, respectively) and lack of preoperative K-L grade in the previous study preclude direct comparison. Systematic reviews comparing QT/QTPB autografts with other types of autografts suggested that the former type provide comparable clinical and functional outcomes, but with reduced donor-site pain.2,13,14,18 Other comparative studies also advocated the use of QT/QTPB autografts due to the lower rates of sensory loss,12 stronger extensor mechanism,1 and superior biomechanical characteristics.16 Fu et al4 reported 5 cases of patella fracture (among 57 patients) after harvesting QTPB autografts proposing a problem specific to the graft; similarly, 6 cases of patella fracture (4 intraoperatively and 2 postoperatively) occurred in the present study.

This study had some limitations. First, retrospectively collected data were analyzed, and no comparison with other graft types was performed. Second, despite similar demographics between the included and excluded patients, there was a possibility of selection bias, as only 139 patients were selected among a total of 372 patients due to the requirement of a long follow-up period. Nevertheless, to the authors’ knowledge, this is the largest study on the clinical results of ACLRs using QTPB autografts reported to date; it also has the longest follow-up period.

CONCLUSION

ACLR using QTPB autograft provides satisfactory long-term clinical results, with acceptable rates of complication and donor-site morbidity.

### Table 3

| Time Point        | Score |
|-------------------|-------|
| Lysholm           |       |
| Preoperative      | 71.2 ± 8.6 |
| 2 years postoperative | 89.8 ± 7.8 |
| 5 years postoperative | 90.2 ± 8.4 |
| Final visit       | 89.8 ± 8.3 |
| Subjective IKDC   |       |
| Preoperative      | 56.8 ± 8.1 |
| 2 years postoperative | 90.9 ± 7.7 |
| 5 years postoperative | 84.8 ± 7.6 |
| Final visit       | 81.0 ± 8.4 |
| Tegner activity scale |     |
| Preoperative      | 3.0 ± 1.4 |
| 2 years postoperative | 4.8 ± 1.3 |
| 5 years postoperative | 4.5 ± 1.2 |
| Final visit       | 4.4 ± 1.3 |

### Table 4

| Complication Type | Complications          | Treatment         |
|-------------------|------------------------|-------------------|
| Rerupture         | 9 (5.8)                | Revision ACLR     |
| Residual instability | 2 (1.3)            | Revision ACLR     |
| Surgical site infection | 2 (1.3)    | Arthroscopic synovectomy and debridement |
| Patellar fracture | 6 (3.9)                | ORIF              |
| Cyclops lesion    | 4 (2.6)                | Arthroscopic excision |
| Arthrofibrosis    | 2 (1.3)                | MUA               |
| Transient LOM     | 6 (3.9)                | Physical therapy  |
| Total             | 31 (20.0)              |                   |

aData are reported as n (%). ACLR, anterior cruciate ligament reconstruction; LOM, limitation of motion; MUA, manipulation under anesthesia; ORIF, open reduction and internal fixation.
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