



## LONG-TERM OUTCOMES OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH DIFFERENT GRAFT CHOICES: A PROSPECTIVE STUDY

Dr. V. Panneer Selvam<sup>1\*</sup>, Dr. N. Sathiya Prakash<sup>2</sup>, Dr. Krishna Balaji P<sup>3</sup>,  
Dr. S. Rajasekaran<sup>4</sup>

<sup>1\*</sup>Assistant Professor, Department of Orthopaedics, Government Dindigul Medical College, Dindigul, Tamil Nadu, India.

<sup>2</sup>Assistant Professor, Department of Orthopaedics, Government Dindigul Medical College, Dindigul, Tamil Nadu, India.

<sup>3</sup>Assistant Professor, Department of Orthopaedics, Government Dindigul Medical College, Dindigul, Tamil Nadu, India.

<sup>4</sup>Head of the Department, Department of Orthopaedics, Government Dindigul Medical College, Dindigul, Tamil Nadu, India.

**Corresponding Author:** Dr. V. Panneer Selvam

**Email:** <sup>1\*</sup>[docpanneerselvam@gmail.com](mailto:docpanneerselvam@gmail.com), <sup>2</sup>[sathyathegr8@gmail.com](mailto:sathyathegr8@gmail.com), <sup>3</sup>[drkaybee89@gmail.com](mailto:drkaybee89@gmail.com), <sup>4</sup>[raju6366@gmail.com](mailto:raju6366@gmail.com)

### ABSTRACT

**Background:** Anterior cruciate ligament (ACL) reconstruction is a commonly performed orthopedic procedure aimed at restoring knee stability and functional performance following ligament injury. The choice of graft plays a crucial role in determining postoperative outcomes. Despite advancements in surgical techniques, the optimal graft choice remains controversial.

**Objectives:** This study aimed to evaluate and compare the functional outcomes and complication rates associated with different graft types used in ACL reconstruction.

**Methods:** A prospective observational study was conducted at a tertiary care centre in Dindigul from January 2023 to December 2025. A total of 148 patients with ACL injury were assessed, of which 120 patients met the inclusion criteria. Patients were categorized into three groups based on graft type: hamstring tendon (HT), bone–patellar tendon–bone (BPTB), and quadriceps tendon (QT). Functional outcomes were evaluated using the Lysholm Knee Score and International Knee Documentation Committee (IKDC) score preoperatively and at 6 months and 12 months postoperatively. Statistical analysis was performed using appropriate tests, and a p-value < 0.05 was considered significant.

**Results:** The mean age of patients was  $28.4 \pm 6.2$  years, with a male predominance (75%). Hamstring grafts were most commonly used (50%), followed by BPTB (30%) and QT (20%). All groups demonstrated significant improvement in functional scores compared to preoperative values ( $p < 0.001$ ). The BPTB group showed slightly higher Lysholm and IKDC scores, indicating better knee stability. However, anterior knee pain was more common in the BPTB group. The HT group showed fewer donor site complications, while QT grafts demonstrated comparable functional outcomes with moderate complication rates.

**Conclusion:** ACL reconstruction using different graft types results in significant improvement in knee function and stability. While BPTB grafts offer superior stability, they are associated with higher donor site morbidity. Hamstring and quadriceps tendon grafts provide comparable outcomes with fewer complications. Although the study reports outcomes at 12 months follow-up, these findings provide early insight into long-term functional trends. Individualized graft selection remains essential for optimal patient outcomes.

### INTRODUCTION

One of the most frequent and clinically severe ligamentous injuries of the knee, anterior cruciate ligament (ACL) injuries primarily afflict young, energetic people and athletes who play pivoting sports like basketball, volleyball, and football.<sup>1</sup>

These injuries frequently cause the knee joint to become functionally unstable, decrease performance, and raise the risk of further injuries such as meniscal tears and articular cartilage loss. ACL deficiency can cause early-onset osteoarthritis and long-term impairment if treatment is not received, which would have a major negative influence on quality of life.<sup>2</sup>

In order to improve functional results, restore knee stability, and allow patients to resume their pre-injury activity levels, ACL reconstruction has emerged as the gold standard treatment.<sup>3</sup> Over the last few decades, improvements in rehabilitation



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procedures, arthroscopic instruments, and surgical techniques have led to better outcomes and lower rates of complications.<sup>4</sup> Despite these developments, a number of variables still affect the outcome of ACL reconstruction, with graft selection continuing to be one of the most contentious and important choices.<sup>5</sup>

The most popular autografts for ACL restoration are quadriceps tendon (QT), hamstring tendon (HT), and bone-patellar tendon-bone (BPTB). Every type of graft has distinct biomechanical traits, healing qualities, and possible side effects that affect both immediate recuperation and long-term functional results.<sup>6</sup> Because hamstring tendon grafts are easy to harvest, require a smaller incision, and have lower donor site morbidity, they are frequently employed. They are linked to improved cosmetic results and less anterior knee pain following surgery. However, issues with potential laxity with time, delayed graft incorporation, and hamstring muscle weakening have been brought up.<sup>7</sup>

On the other hand, many orthopedic surgeons have long regarded bone-patellar tendon-bone grafts as the gold standard. Bone-to-bone healing, which enables quicker graft integration and more robust initial fixation, is the main benefit of BPTB grafts.<sup>8</sup> This frequently results in reduced rates of graft elongation and increased knee stability. These advantages, however, come at the expense of increased donor site morbidity, which can be especially troublesome for some occupational groups and include anterior knee discomfort, patellar fractures, and kneeling difficulties.<sup>9</sup>

In recent years, there has been a growing interest in quadriceps tendon grafts as a potential substitute. Compared to BPTB grafts, they provide a greater graft diameter, advantageous biomechanical strength, and a decreased frequency of anterior knee pain. Furthermore, several studies show that QT grafts had less donor site problems than both HT and BPTB grafts. Despite these benefits, their usage has typically been restricted because of unfamiliarity and comparatively few long-term outcome studies, while new data points to encouraging outcomes.<sup>10</sup> Numerous patient-specific and physician-related criteria, such as age, activity level, occupation, related injuries, anatomical considerations, and surgeon expertise, affect the choice of graft type. For example, athletes who play high-demand sports can benefit from grafts that provide better stability, while people who work in jobs that require them to kneel frequently might choose grafts that reduce the likelihood of anterior knee pain. As a result, customized graft selection is essential to achieving the best results.<sup>11</sup>

Despite the fact that many studies have assessed the results of ACL restoration, many of them are constrained by retrospective designs, brief follow-up periods, or comparisons of just two graft types. To give more trustworthy and clinically useful results,

well-designed prospective studies comparing various graft alternatives within the same cohort are still needed. Furthermore, context-specific research is required due to geographical differences in patient demographics, injury patterns, and activity levels.<sup>12</sup> Understanding the results of various graft options becomes even more important in semi-urban settings like Dindigul, where occupational demands and access to healthcare resources may differ from metropolitan areas. The relative lack of data from these areas emphasizes how crucial it is to carry out localized prospective research.

In order to compare and prospectively assess the long-term clinical and functional results of ACL reconstruction using hamstring tendon, bone-patellar tendon-bone, and quadriceps tendon grafts in patients receiving treatment at a tertiary care facility in Dindigul, the current study was conducted. The study's objectives are to evaluate postoperative functional ratings, examine complication rates, and pinpoint variables affecting graft choice and results. This study aims to enhance patient care in ACL reconstruction and support evidence-based decision-making by offering comparative and region-specific data.<sup>13</sup>

Unlike previous studies, this study provides prospective comparative data from a semi-urban Indian population, highlighting region-specific variations in injury patterns, graft selection, and functional outcomes.

## MATERIALS AND METHODS

This prospective observational study was conducted at a tertiary care center in Dindigul over a period of three years (January 2023 to December 2025). The study aimed to evaluate the long-term functional and clinical outcomes of anterior cruciate ligament (ACL) reconstruction using different graft choices. The study was approved by the Institutional Ethics Committee, and informed consent was obtained from all participants.

### Study Population and Sampling

A total of 148 patients presenting with symptomatic ACL injury were initially assessed for eligibility. After applying predefined inclusion and exclusion criteria, 120 patients were included in the final analysis. All patients were followed up for a minimum period of 12 months. Postoperative follow-up was conducted at 6 months and 12 months, during which functional outcomes, knee stability, and complications were assessed.

### Patient Screening and Exclusion Details

Among the 148 patients initially assessed, 10 were excluded due to multi-ligament injuries, 6 had a history of previous knee surgery, 5 had severe osteoarthritis, and 7 were lost to follow-up before surgery. After applying these exclusion criteria, a total of 28 patients were excluded and the remaining 120 patients were included in the final analysis.

This exclusion process ensured a homogeneous study population and improved the reliability of the outcomes.

**Inclusion Criteria**

- Patients aged between 18 and 45 years.
- Patients with clinically and radiologically confirmed ACL tear.
- Patients with isolated ACL injury or ACL injury associated with meniscal injury.
- Patients who were willing to undergo surgical intervention.
- Patients with complete clinical and imaging records.
- Patients who were willing to participate and comply with follow-up protocol.

**Exclusion Criteria**

- Patients with multi-ligament knee injuries.
- Patients with previous history of knee surgery.
- Patients with advanced osteoarthritis of the knee joint.
- Patients with systemic illness affecting mobility or rehabilitation.
- Patients with incomplete clinical data or records.
- Patients who were unwilling to participate or did not complete follow-up.

**Group Allocation**

Patients were categorized into three groups based on the graft used during reconstruction:

- Group A: Hamstring tendon graft (HT)
- Group B: Bone–patellar tendon–bone graft (BPTB)
- Group C: Quadriceps tendon graft (QT)

The choice of graft was based on patient factors, activity level, and surgeon preference.

**Surgical Technique**

All procedures were performed arthroscopically under spinal or general anesthesia by experienced orthopedic surgeons. Standard anteromedial and anterolateral portals were used. Femoral and tibial tunnels were created using anatomical landmarks. Graft fixation was achieved using interference screws or appropriate fixation devices depending on graft type. Meniscal injuries, if present, were addressed simultaneously.

**Postoperative Rehabilitation**

All patients followed a standardized rehabilitation protocol. Early mobilization was encouraged, with progressive weight-bearing initiated as tolerated. Range of motion exercises, quadriceps strengthening, and proprioceptive training were implemented in a phased manner. Return to sports was typically allowed after 6–9 months based on functional recovery.

**Data Collection**

Baseline demographic data including age, sex, and mechanism of injury were recorded. Preoperative clinical evaluation included assessment using the Lysholm Knee Score and International Knee Documentation Committee (IKDC) score.

Postoperative follow-up was conducted at 6 months and 12 months. At each follow-up, functional outcomes, knee stability, and complications were assessed.

**Outcome Measures**

Primary outcome measures included:

- Functional scores (Lysholm and IKDC scores)
- Knee stability assessment

Secondary outcome measures included:

- Complications such as anterior knee pain, infection, and graft failure

**Statistical Analysis**

Data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation, and categorical variables were presented as frequencies and percentages. Comparison between the three graft groups was performed using ANOVA test. Preoperative and postoperative scores were compared using paired t-test. Complications were analyzed using chi-square test. A p-value of <0.05 was considered statistically significant. Post-hoc analysis was performed to identify intergroup differences where applicable.

**RESULTS**

A total of 148 patients were initially assessed for eligibility, of which 28 patients were excluded based on predefined criteria. The remaining 120 patients were included in the final analysis. All patients were followed up for a minimum period of 12 months. Statistical analysis showed significant improvement in functional outcomes across all graft groups.

Table 1: Demographic Details

| Variable              | Value    |
|-----------------------|----------|
| Male                  | 90 (75%) |
| Female                | 30 (25%) |
| Sports Injury         | 72 (60%) |
| Road Traffic Accident | 48 (40%) |

**Table Note:** Data are presented as frequency (n) and percentage (%). Majority of patients were young

males, with sports injuries being the most common cause.

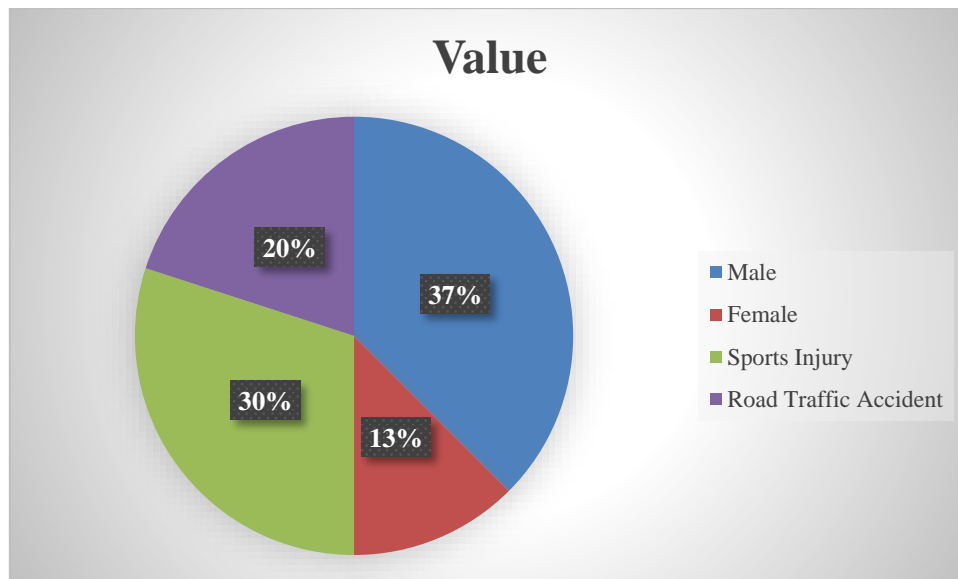


Figure 1: Distribution of Gender and Mechanism of Injury

**Figure Note:** This figure illustrates the distribution of patients based on gender, and mechanism of injury. The majority of patients were young males,

with sports-related injuries being the most common cause of ACL tears.

Table 2: Graft Type Distribution

| Graft Type      | Number (%) |
|-----------------|------------|
| Hamstring (HT)  | 60 (50%)   |
| BPTB            | 36 (30%)   |
| Quadriceps (QT) | 24 (20%)   |

**Table Note:** Data are expressed as number (n) and percentage (%). Hamstring graft was the most frequently used graft in this study.

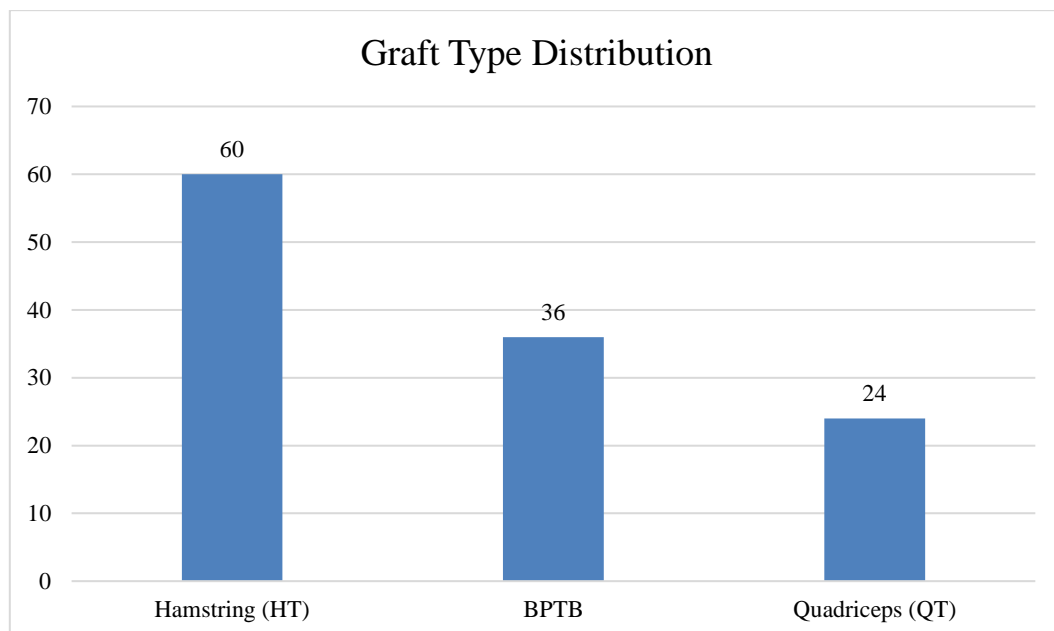


Figure 2: Distribution of Graft Types Used in ACL Reconstruction

**Figure Note:** This figure represents the proportion of different graft types used in the study. Hamstring tendon grafts were the most commonly used,

followed by bone–patellar tendon–bone and quadriceps tendon grafts.

Table 3: Preoperative Clinical Scores

| Score         | Mean ± SD  |
|---------------|------------|
| Lysholm Score | 54.2 ± 8.1 |
| IKDC Score    | 48.5 ± 7.6 |

**Table Note:** Values are presented as mean ± standard deviation, indicating poor functional status before surgery.

Table 4: Postoperative Outcomes

| Graft | Lysholm Score | IKDC Score |
|-------|---------------|------------|
| HT    | 89.5 ± 5.2    | 86.3 ± 4.8 |
| BPTB  | 91.2 ± 4.6    | 88.1 ± 4.2 |
| QT    | 88.7 ± 5.5    | 85.9 ± 5.0 |

**Table Note:** ANOVA test showed a statistically significant difference between groups ( $p < 0.05$ ). There was a statistically significant improvement in Lysholm and IKDC scores in all groups compared to

preoperative values ( $p < 0.001$ ). Post-hoc comparison showed that BPTB grafts had significantly higher scores compared to HT and QT groups ( $p < 0.05$ ).

Table 5: Complications

Chi-square test showed no statistically significant difference in complication rates between groups ( $p = 0.08$ ).

| Complication       | HT | BPTB | QT |
|--------------------|----|------|----|
| Anterior Knee Pain | 5  | 12   | 6  |
| Infection          | 2  | 3    | 1  |
| Graft Failure      | 3  | 4    | 2  |

**Table Note:** Chi-square test was used for analysis. No statistically significant difference was observed ( $p > 0.05$ ).

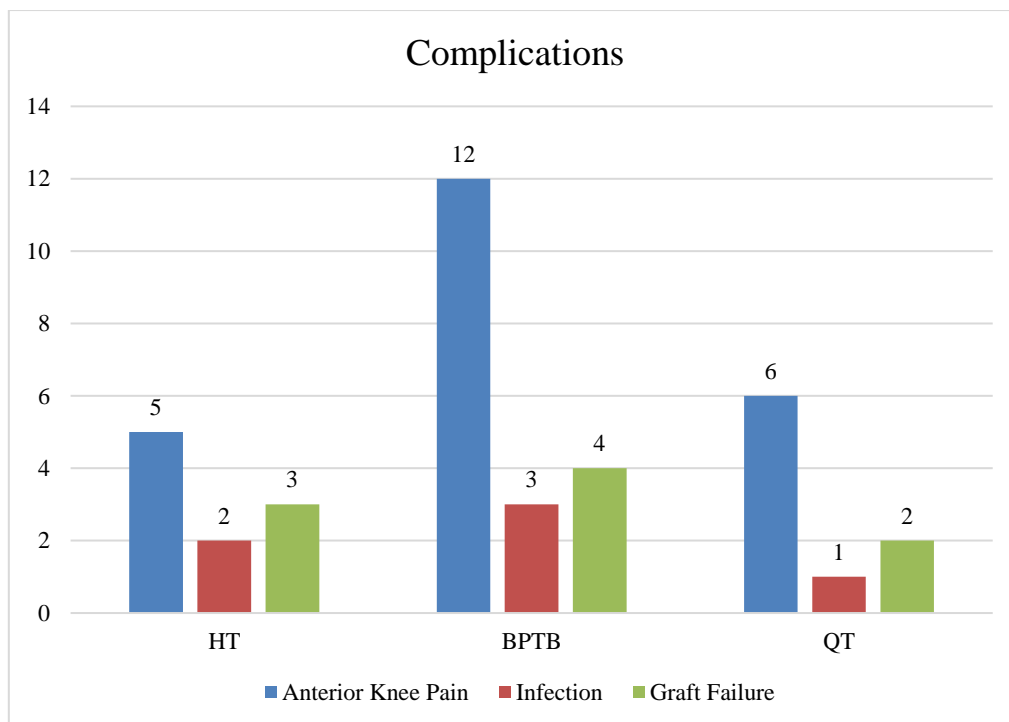


Figure 3: Comparison of Postoperative Functional Outcomes across Graft Types

**Figure Note:** This figure shows the comparison of mean postoperative Lysholm and IKDC scores among the three graft groups. All graft type's demonstrated significant improvement, with slightly higher scores observed in the BPTB group.

## DISCUSSION

The present study provides valuable insight into the comparative effectiveness of commonly used grafts in anterior cruciate ligament (ACL) reconstruction within a tertiary care setting. The results reinforce the understanding that ACL reconstruction, irrespective of graft choice, leads to significant improvement in knee function and patient-reported

outcomes, as evidenced by the marked increase in Lysholm and IKDC scores across all groups.<sup>14</sup>

The findings of this study are particularly relevant in semi-urban populations where occupational demands and lifestyle factors differ from urban settings. This adds important regional context to existing literature.

The slightly superior functional scores observed in the BPTB group align with existing literature that highlights the advantages of bone-to-bone healing and rigid fixation. These results are consistent with previous studies by Gupta et al., which reported superior stability with BPTB grafts due to bone-to-bone healing. These properties likely contribute to improved graft incorporation and knee stability, especially in high-demand individuals such as athletes. However, this benefit must be carefully weighed against the higher incidence of anterior knee pain noted in this group. Donor site morbidity, particularly pain during kneeling and activities involving direct pressure on the patella, remains a significant drawback and may impact patient satisfaction in the long term.<sup>15</sup>

Hamstring tendon grafts demonstrated a favourable balance between functional outcomes and complication rates. The lower incidence of anterior knee pain and reduced donor site morbidity make HT grafts particularly suitable for patients with occupational or cultural activities involving frequent kneeling or squatting. However, concerns regarding potential hamstring weakness and graft laxity over time should not be overlooked, especially in physically active populations.<sup>16</sup> Similar observations have been reported in earlier studies where hamstring grafts demonstrated lower donor site morbidity and better patient comfort.

Quadriceps tendon grafts, though less commonly utilized, showed comparable functional outcomes with moderate complication rates. Their increasing popularity can be attributed to their robust biomechanical properties and relatively lower donor site morbidity compared to BPTB grafts. The findings of this study support the growing body of evidence that QT grafts are a reliable alternative, particularly in revision surgeries or when other graft options are contraindicated.<sup>17</sup> Recent literature supports the increasing use of quadriceps tendon grafts due to their favorable biomechanical properties and reduced anterior knee pain.

An important observation from this study is the absence of a single superior graft option. Instead, outcomes appear to be influenced by a combination of graft characteristics, patient-specific factors, surgical technique, and adherence to rehabilitation protocols. This underscores the importance of individualized treatment planning.<sup>18</sup>

Overall, the study contributes to existing knowledge by providing prospective data from a regional population, emphasizing that optimal outcomes in ACL reconstruction are best achieved through a

tailored approach rather than a uniform graft selection strategy.<sup>19</sup>

Although the present study reports outcomes at 12 months follow-up, these findings provide an early indication of long-term functional trends following ACL reconstruction.

### Limitations

This study has certain limitations that should be considered while interpreting the results. It was conducted as a single centre study, which may limit the generalizability of the findings to other populations. The sample size, although adequate, was relatively moderate, and larger multicentric studies are required for broader validation. The study duration and follow-up period were limited to 12 months, which may not fully reflect long-term graft survival and late complications. In addition, randomization was not performed, and graft selection was based on surgeon preference, which may introduce selection bias.

Furthermore, objective assessment tools such as instrumented laxity measurements and radiological evaluation were not included. Future studies incorporating longer follow-up, larger populations, and additional objective parameters would provide more comprehensive evidence. The absence of randomization and blinding may have introduced selection bias and influenced the outcomes.

### Clinical Implications

The findings of this study have important clinical implications. Graft selection should be individualized based on patient activity level, occupational requirements, and risk of donor site morbidity. BPTB grafts may be preferred in high-demand athletes requiring superior stability, whereas hamstring grafts may be more suitable for patients requiring minimal postoperative discomfort.

### CONCLUSION

ACL reconstruction using hamstring tendon, bone–patellar tendon–bone, and quadriceps tendon grafts results in significant improvement in knee function and stability. BPTB grafts offer slightly superior stability but are associated with higher incidence of anterior knee pain, whereas hamstring grafts provide lower donor site morbidity. Quadriceps tendon grafts represent a reliable alternative with comparable outcomes. Graft selection should be individualized based on patient characteristics and surgeon expertise.

Overall, the study highlights that no single graft is universally superior. Individualized graft selection based on patient characteristics, activity level, and surgeon expertise plays a crucial role in achieving optimal outcomes. Incorporation of appropriate graft choice and standardized rehabilitation protocols can significantly enhance long-term success following ACL reconstruction.

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