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# Evaluation of Functional Recovery After Five-Strand Hamstring Autograft Anterior Cruciate Ligament Reconstruction Using Validated IKDC and KOOS Instruments: A Single-Center Prospective Observational Study in South India.

**Dr Vignesh Raj S[1], Dr. Vijay Narasimman Reddy[2], Dr Shiva Shankaran G B[3]**
[1]Post Graduate resident,Department of Orthopaedics,Sree Balaji Medical College and Hospital, No 7 CLC Works road, Chrompet - 600044, Chennai, Tamil Nadu, India.
vigneshraj95@gmail.com
[2]Head of Department,Dept of Orthopaedics,Sree Balaji medical college and hospital
No 7 CLC Works road, Chrompet - 600044, Chennai, Tamil Nadu, India
vijayanarasimhan2003@yahoo.co.in
[3]Assistant Professor,Sree Balaji Medical College and hospitals Chennai,Dept of Orthopaedics, Sree Balaji medical college and hospital,No 7 CLC Works road, Chrompet - 600044, Chennai, Tamil Nadu, India,:shivaseenu.gbkshiva@gmail.com

***ABSTRACT***

*Background: Anterior cruciate ligament (ACL) injuries are common in young, active individuals and often necessitate surgical reconstruction for optimal functional recovery. The five-strand hamstring autograft technique has been proposed to overcome the limitations of grafts with insufficient diameter, potentially enhancing biomechanical strength and clinical outcomes.*

*Methods: This single-center, prospective observational study was conducted at a tertiary care hospital in Tamil Nadu between January 2024 and June 2025. A total of 35 patients aged 18-45 years with isolated ACL tears underwent arthroscopic reconstruction using a five-strand hamstring autograft. Functional outcomes were assessed using the International Knee Documentation Committee (IKDC) score and the Knee Injury and Osteoarthritis Outcome Score (KOOS) at baseline, 6 weeks, 6 months, and 12 months. Statistical analysis was performed using the Friedman test and Wilcoxon signed-rank test for repeated measures.*

*Results: The median IKDC score improved from 32.0 preoperatively to 84.0 at 12 months, while the KOOS overall score increased from 29.0 to 88.0 during the same period, both showing statistically significant improvements ($p < 0.001$). The steepest functional gains were observed between 6 weeks and 6 months postoperatively. Complications were minimal, with only one superficial surgical site infection (2.86%) and two cases of stiffness (5.71%).*

*Conclusion: Five-strand hamstring autograft ACL reconstruction is a safe and effective technique that results in significant functional improvement as measured by IKDC and KOOS scores. It offers a reliable solution in patients with smaller tendon diameters, ensuring graft adequacy and robust recovery.*

***Keywords:*** *ACL reconstruction, five-strand hamstring graft, IKDC, KOOS, functional outcome, knee injury, autograft, arthroscopy.*

## INTRODUCTION

Anterior cruciate ligament (ACL) injuries represent one of the most common ligamentous injuries of the knee, particularly affecting young and physically active individuals engaged in sports or high-demand occupational activities. (1) The ACL serves a pivotal role in maintaining anteroposterior and rotational stability of the knee joint. Rupture of this ligament not only

compromises joint biomechanics but also predisposes patients to persistent instability, reduced functional capacity, and a higher risk of early-onset osteoarthritis if not appropriately addressed. With the increasing incidence of ACL injuries, there has been a corresponding emphasis on refining surgical reconstruction techniques to restore optimal knee function and prevent long-term complications. (2)

Arthroscopic ACL reconstruction using autologous grafts remains the gold standard for surgical management. Among the various graft choices, hamstring tendon autografts typically fashioned from the semitendinosus and gracilis tendons are widely preferred due to their favourable biomechanical properties, reduced donor-site morbidity, and excellent long-term functional outcomes. (3) However, a critical determinant of graft success lies in its diameter. Evidence from biomechanical and clinical studies indicates that grafts with diameters less than 8 mm are associated with higher rates of graft failure and suboptimal clinical outcomes, particularly in younger patients with higher physical demands. (4)

To address the limitation of smaller graft diameters, the five-strand hamstring graft technique has been introduced. This method involves tripling the semitendinosus and doubling the gracilis tendon to increase the overall cross-sectional diameter of the graft, thereby enhancing its tensile strength and mechanical stability. This modification is especially beneficial in individuals with anatomically small tendons, where standard four-strand grafts may be inadequate. Preliminary clinical studies and biomechanical investigations have suggested that the five-strand construct offers superior graft diameter, improved resistance to failure, and comparable, if not superior, functional outcomes when compared to traditional techniques. (5)

Assessment of postoperative outcomes following ACL reconstruction requires both objective and patient-reported outcome measures. (6) The International Knee Documentation Committee (IKDC) score is a widely validated tool that provides a comprehensive assessment of knee function, symptoms, and activity levels from the patient's perspective. (7) It serves as a reliable indicator of objective functional recovery. Complementing this, the Knee injury and Osteoarthritis Outcome Score (KOOS) extends the assessment to five critical domains: pain, other symptoms, activities of daily living, function in sport and recreation, and knee-related quality of life. KOOS is particularly suited for younger and active populations undergoing knee ligament reconstruction, offering detailed insights into the subjective recovery trajectory and the impact of surgery on daily life and athletic performance. (8) While the biomechanical advantages of the five-strand technique have been demonstrated, there remains a relative paucity of clinical studies that employ both IKDC and KOOS scores to comprehensively evaluate the postoperative functional outcomes of this graft configuration. (9) The present study was thus undertaken to bridge this gap in the literature. It prospectively evaluates the functional recovery in patients undergoing five-strand ACL reconstruction, using the IKDC score as a measure of objective functional improvement and the KOOS as a measure of subjective symptoms and quality of life. This dual-instrument approach aims to provide a more holistic understanding of the efficacy and utility of the five-strand technique in contemporary ACL reconstruction.

## MATERIALS AND METHODS

This study was designed as a single-center, prospective observational study conducted in the Department of Orthopaedics at a tertiary care hospital in Tamil Nadu. The study was carried out over a period of 18 months, from January 2024 to June 2025. Ethical clearance was obtained prior to the commencement of the study from the Institutional Ethics Committee (IEC) of the institute (Approval No: HIEC/ORTHO/2024/056) and written informed consent was obtained from all study participants after explaining the nature, purpose, and potential risks involved in the study, in accordance with the Declaration of Helsinki.

The study population consisted of patients aged 18 to 45 years presenting with a clinical and radiological diagnosis of isolated anterior cruciate ligament tear. Inclusion criteria comprised skeletally mature individuals with no previous surgical intervention on the affected knee, those willing to undergo ACL reconstruction using a five-strand hamstring autograft, and individuals consenting to participate and comply with the follow-up protocol. Patients were excluded if they had multi-ligamentous injuries, concomitant significant osteoarthritis (Kellgren-Lawrence grade >2), active infection, previous surgeries on the affected knee, neuromuscular disorders, or contraindications to surgery or general anaesthesia.

The minimum sample size required for the study was estimated using the formula for paired means: $n = (Z_a + Z_\beta)^2 \times \sigma^2 / d^2$, where $Z_a$ = 1.96 for 95% confidence interval, $Z_\beta$ = 0.84 for 80% power, $\sigma$ (standard deviation) = 12 (as per a previous study assessing IKDC score changes), (10) and $d$ (minimum clinically significant difference) = 8. Substituting these values yielded a minimum required sample size of 30 patients. To account for potential attrition or loss to follow-up, a final sample size of 35 patients was recruited.

A consecutive sampling technique was employed, wherein all eligible patients presenting to the Orthopaedic outpatient department and fulfilling the inclusion and exclusion criteria during the study period were invited to participate until the required sample size was achieved. Prior to data collection, a semi-structured, pre-tested questionnaire was developed to gather socio-demographic details, clinical history, injury characteristics, and baseline functional scores. The questionnaire was reviewed for face and content validity by a panel of three subject experts and was subsequently pilot-tested on five patients not included in the final study to ensure comprehensibility, consistency, and applicability. Necessary modifications were made based on pilot feedback.

All surgical procedures were performed by the same senior orthopaedic surgeon experienced in arthroscopic ACL reconstructions to maintain consistency in operative technique and reduce inter-surgeon variability. The five-strand hamstring autograft was prepared intraoperatively by tripling the semitendinosus and doubling the gracilis tendons, yielding a thickened graft diameter of ≥9 mm. Standard arthroscopic techniques were employed for tunnel creation, femoral fixation was achieved using an EndoButton (Smith & Nephew), and tibial fixation was secured using a bio-absorbable interference screw. All patients underwent the same standardized postoperative rehabilitation protocol under the supervision of a trained physiotherapist, beginning with early range of motion exercises followed by progressive strengthening and return-to-sport activities by the third postoperative month.

Functional outcomes were assessed using two validated scoring systems. The International Knee Documentation Committee (IKDC) subjective knee evaluation form was used to objectively assess functional performance, knee stability, and symptoms, while the Knee Injury and Osteoarthritis Outcome Score (KOOS) was employed to evaluate pain, symptoms, activities of daily living, sports/recreation function, and knee-related quality of life. These scores were administered at baseline (preoperatively), and at 6 weeks, 6 months, and 12 months postoperatively by a trained research assistant who was blinded to surgical details to minimize observer bias. The same version of the questionnaire was used at all time points to ensure consistency.

To ensure data quality and reliability, the research assistant underwent structured training regarding questionnaire administration, patient interaction, and outcome scoring. Mock interviews and scoring sessions were conducted prior to the actual data collection. The measurement tools (i.e., printed forms and digital records) were calibrated and validated for accuracy. Data entry was performed in Microsoft Excel with double data entry validation to prevent transcription errors. Any discrepancies identified during data cleaning were resolved by

cross-checking with original patient records. Statistical analysis was performed using IBM SPSS Statistics Version 28. Descriptive statistics were computed for demographic and clinical variables. Continuous variables were expressed as means and standard deviations or medians and interquartile ranges based on data distribution, while categorical variables were summarized using frequencies and percentages. The normality of distribution was tested using the Shapiro-Wilk test. Changes in IKDC and KOOS scores over the follow-up period were analyzed using the Friedman test for repeated measures, and post hoc pairwise comparisons were conducted with the Wilcoxon signed-rank test. A p-value of less than 0.05 was considered statistically significant.

## RESULTS

The present study included 35 patients who underwent five-strand hamstring autograft ACL reconstruction. The majority of participants were males (97.1%) with a mean age of 28.6 ± 6.5 years. Right-sided ACL tears were more common (57.1%) than left-sided injuries, and sports-related trauma was the leading cause of injury (45.7%). Nearly half the patients (51.4%) underwent surgery within 3 months of injury. Associated meniscal injuries were present in 40% of cases, with lateral meniscus involvement being more common than medial (Table 1).

**Table 1. Baseline Demographic and Clinical Characteristics of Study Participants (n = 35)**

| **Variable** | **Value** |
|---|---|
| **Age (years), mean ± SD** | 28.6 ± 6.5 |
| **Age Group, n** (%) | |
| 18–25 years | 13 (37.1%) |
| 26–35 years | 12 (34.3%) |
| 36–45 years | 10 (28.6%) |
| **Sex, n** (%) | |
| Male | 34 (97.1%) |
| Female | 1 (2.9%) |
| **Side of Injury, n** (%) | |
| Right | 20 (57.1%) |
| Left | 15 (42.9%) |
| **Duration from Injury to Surgery, n** (%) | |
| < 3 months | 18 (51.4%) |
| 3–6 months | 10 (28.6%) |
| > 6 months | 7 (20.0%) |
| **Mode of Injury, n** (%) | |
| Sports-related | 16 (45.7%) |
| Road traffic accident | 12 (34.3%) |
| Fall / Other | 7 (20.0%) |
| **Associated Meniscal Injury, n** (%) | |
| Present | 14 (40.0%) |
| Absent | 21 (60.0%) |

The distribution of diagnostic categories revealed that the most frequent diagnosis was isolated right ACL tear (31.43%), followed by left ACL tear (25.71%). Combined injuries with medial or lateral meniscal involvement accounted for nearly 43% of all cases. Right ACL tears were more frequently associated with meniscal injuries than left-sided tears (Table 2).

**Table 2. Distribution of Study Participants Based on Diagnosis (n = 35)**

| **S. No.** | **Diagnosis** | **Frequency (n)** | **Percentage** (%) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | Left ACL Tear | 9 | 25.71 |
| 2 | Left ACL Tear + Left Lateral Meniscus Tear | 5 | 14.29 |
| 3 | Left ACL Tear + Left Medial Meniscus Tear | 3 | 8.57 |
| 4 | Right ACL Tear | 11 | 31.43 |
| 5 | Right ACL Tear + Right Medial Meniscus Tear | 5 | 14.29 |
| 6 | Right ACL Tear + Right Lateral Meniscus Tear | 2 | 5.71 |
| | **Total** | **35** | **100.00** |

Surgical procedures mirrored the diagnostic profile, with isolated right ACL reconstructions being the most commonly performed intervention (31.43%), followed by isolated left ACL reconstructions (25.71%). Combined ACL reconstruction with meniscal repairs was required in 45.7% of cases, most frequently involving medial meniscal repair on the right side (Table 3).

**Table 3. Distribution of Surgical Procedures Performed (n = 35)**

| S. No. | Procedure Done | Frequency (n) | Percentage (%) |
|---|---|---|---|
| 1 | Left ACL Reconstruction | 9 | 25.71 |
| 2 | Left ACL Reconstruction + Lateral Meniscus Repair | 5 | 14.29 |
| 3 | Left ACL Reconstruction + Medial Meniscus Repair | 3 | 8.57 |
| 4 | Right ACL Reconstruction | 11 | 31.43 |
| 5 | Right ACL Reconstruction + Lateral Meniscus Repair | 2 | 5.71 |
| 6 | Right ACL Reconstruction + Medial Meniscus Repair | 5 | 14.29 |
| | **Total** | **35** | **100.00** |

t baseline, the median preoperative IKDC score was 32.0 (IQR: 28.0–36.0), and the median KOOS overall score was 29.0 (IQR: 24.0–33.0). Among the KOOS subdomains, the lowest scores were observed in the Sports/Recreation and QoL components, reflecting significant impairment in patient-reported knee-related quality of life and athletic participation (Table 4).

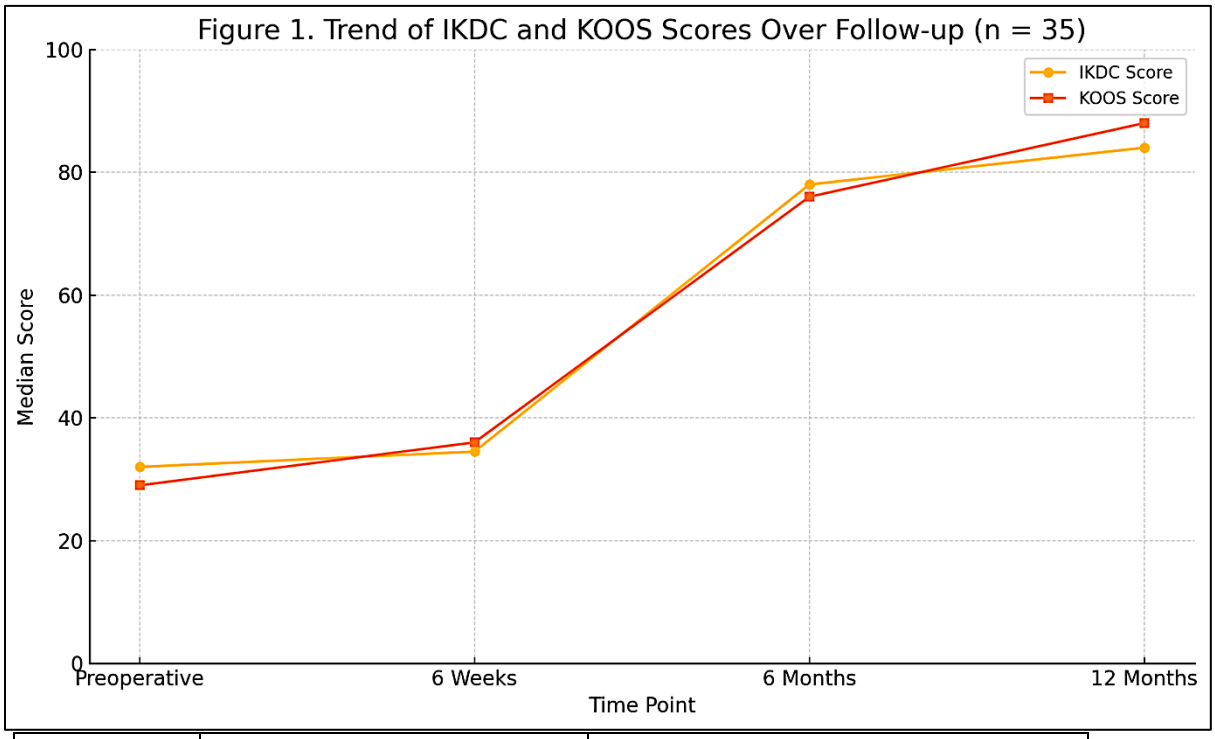
**Table 4. Baseline Preoperative Functional Scores Assessed Using IKDC and KOOS Instruments (n = 35)**

| Score Instrument | Median (IQR) |
|---|---|
| IKDC Score (Preoperative) | 32.0 (28.0–36.0) |
| KOOS Overall Score (Preoperative) | 29.0 (24.0–33.0) |
| KOOS – Pain Subscale | 34.0 (28.0–40.0) |
| KOOS – Symptoms Subscale | 30.0 (26.0–36.0) |
| KOOS – Activities of Daily Living (ADL) Subscale | 35.0 (30.0–42.0) |
| KOOS – Sports and Recreation Subscale | 20.0 (16.0–24.0) |
| KOOS – Quality of Life (QoL) Subscale | 18.0 (14.0–22.0) |

Functional recovery showed progressive improvement over time. The median IKDC score improved from 32.0 at baseline to 84.0 at 12 months, while the KOOS overall score increased from 29.0 to 88.0 over the same period. Statistically significant gains were observed across all follow-up points. There was a significant difference between the preoperative and post operative scores (p-values <0.001). The steepest improvements were seen between 6 weeks and 6 months, aligning with expected postoperative recovery patterns (Table 5 and Figure 1).

**Table 5. Longitudinal Change in IKDC and KOOS Scores Over Follow-up (n = 35)**

| Time Point | IKDC Score, Median (IQR) | KOOS Overall Score, Median (IQR) |
|---|---|---|
| Preoperative | 32.0 (28.0–36.0) | 29.0 (24.0–33.0) |




| | | |
|---|---|---|
| 6 Weeks | 34.5 (30.0–38.0) | 36.0 (32.0–40.0) |
| 6 Months | 78.0 (72.0–82.0) | 76.0 (70.0–80.0) |
| 12 Months | 84.0 (80.0–88.0) | 88.0 (84.0–91.0) |

Postoperative complications were minimal. Two patients (5.71%) experienced knee stiffness requiring physiotherapy beyond the standard protocol, while one patient (2.86%) developed a superficial surgical site infection, managed conservatively. No cases of graft re-rupture or revision surgery were reported, and 91.43% of patients had no postoperative complications (Table 6).

**Table 6. Postoperative Complications and Adverse Events (n = 35)**

| S. No. | Complication or Adverse Event | Frequency (n) | Percentage (%) |
|---|---|---|---|
| 1 | Superficial Surgical Site Infection | 1 | 2.86 |
| 2 | Knee Joint Stiffness Requiring Extended Physiotherapy | 2 | 5.71 |
| 3 | Graft Re-Rupture Within 6 Months | 0 | 0.00 |
| 4 | No Complications Reported | 32 | 91.43 |

## DISCUSSION

The present prospective observational study aimed to evaluate the functional recovery of patients undergoing anterior cruciate ligament (ACL) reconstruction using the five-strand hamstring autograft technique, with outcomes assessed through two validated instruments: the International Knee Documentation Committee (IKDC) score and the Knee Injury and Osteoarthritis Outcome Score (KOOS). The findings indicate a statistically and clinically significant improvement in both objective and subjective functional scores at each follow-up time point postoperatively, with particularly sharp gains observed between the 6-week and 6-month intervals. These results reinforce the efficacy of the five-strand graft technique in promoting functional restoration, symptom relief, and improved quality of life in patients with ACL injuries.

Our findings are in line with an expanding body of literature supporting the clinical utility of the five-strand hamstring autograft. In our cohort, the median IKDC score improved from 32.0 preoperatively to 84.0 at 12 months, while the KOOS score increased from 29.0 to 88.0 in the

same period. These improvements mirror those observed in the study by Wash et al. (11), who reported a rise in IKDC scores from 32.5 to 83.45 within 12 months of surgery using the five-strand technique. Similarly, Kumar et al., (12) demonstrated substantial improvement in IKDC scores (from 43.22 to 92.6) over a 6-month period in young adults, along with reductions in pain and return to activity.

A major advantage of the five-strand configuration lies in its ability to overcome one of the principal biomechanical limitations of conventional four-strand grafts suboptimal graft diameter. Multiple studies have now established that hamstring autografts with diameters less than 8 mm are associated with higher risks of graft failure, particularly in young and athletic populations. Rhatomy et al., (13) found that patients with grafts >8 mm had significantly better KOOS and IKDC scores than those with smaller grafts. In our study, the five-strand configuration allowed for consistent achievement of graft diameters ≥9 mm, thereby mitigating this risk and potentially enhancing graft durability.

Several comparative studies have shown that five-strand grafts are at least equivalent, if not superior, to four-strand grafts in terms of functional outcomes. Krishna et al., (14) reported that five-strand autografts offered outcomes comparable to those of four-strand grafts with diameters ≥8 mm, suggesting that the five-strand technique is particularly useful for patients with undersized hamstring tendons. In our study population, which consisted predominantly of South Indian males a demographic known to have relatively smaller tendon diameters the five-strand technique was highly effective, with 100% of grafts meeting the ≥9 mm threshold. This aligns with findings from Wan et al., (15) who showed that the five-strand configuration consistently increased graft size without compromising short-term outcomes. While some studies suggest that five-strand grafts might offer marginally better performance in KOOS subdomains such as "Symptoms" and "Quality of Life" Krishna et al., (16) others, like Villegas et al., (17) report no statistically significant differences between four- and five-strand techniques. Nevertheless, given the ease of achieving ideal graft diameter with the five-strand method, its clinical utility remains clear especially for patients at higher risk of failure due to anatomical or biomechanical factors.

**Clinical Implications**

These findings carry important implications for clinical practice, particularly in regions where patients often present with smaller hamstring tendons and where achieving an optimal graft diameter using conventional techniques can be challenging. The five-strand technique allows surgeons to construct a thicker, stronger graft without requiring allografts or alternative graft sources, thereby preserving autologous donor-site advantages. Additionally, the reproducible improvements observed in both IKDC and KOOS scores support the technique's role in promoting holistic recovery not only in joint stability but also in patient-perceived quality of life and athletic function. Future research should include multicenter randomized controlled trials comparing five-strand and four-strand techniques across diverse populations with larger sample sizes and long-term follow-up. Investigating biomechanical properties, return-to-sport timelines, and patient satisfaction could further inform best practices in graft selection for ACL reconstruction. (18)

**Strengths and limitations**

The strengths of this study lie in its prospective design, standardized surgical and rehabilitation protocols, and the dual use of IKDC and KOOS scores both of which are validated, patient-centered tools that capture objective function and subjective well-being. The inclusion of a well-defined cohort from a South Indian tertiary care center also adds a unique regional perspective to the growing global literature on ACL reconstruction techniques. Moreover, the use of the five-strand hamstring graft in a population known for relatively smaller tendon anatomy provides

practical insight into the advantages of this technique for enhancing graft strength and preventing failure in high-risk demographics. Despite its contributions, the study is not without limitations. First, the sample size of 35 participants, while adequate for detecting significant within-subject changes, limits the external generalizability of the findings. Second, the absence of a control group such as patients undergoing four-strand graft reconstruction prevents direct comparisons of technique efficacy. Third, the follow-up duration of 12 months, although sufficient to assess early to mid-term outcomes, is not long enough to evaluate long-term complications, graft survivorship, or osteoarthritic changes. Finally, although patient-reported outcomes provide valuable insights, objective functional performance measures such as hop tests or isokinetic strength testing were not included.

## CONCLUSION

In conclusion, the five-strand hamstring autograft technique offers a reliable, biomechanically advantageous, and clinically effective option for ACL reconstruction. This study demonstrates that the technique leads to substantial improvements in both objective (IKDC) and subjective (KOOS) functional scores with minimal postoperative complications. Given its ability to achieve ideal graft diameters in anatomically small tendons, the five-strand method should be considered a valuable alternative in contemporary ligament reconstruction, particularly in populations at higher risk of graft insufficiency with traditional constructs.

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