Clinical Outcomes of Five-Strand Versus Quadruple Hamstring Autograft in Anterior Cruciate Ligament Reconstruction

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ABSTRACT

Background: Anterior cruciate ligament (ACL) reconstruction using hamstring autografts is a standard surgical approach, but graft diameter and strength remain critical factors for stability. The five-strand hamstring autograft technique has emerged as a potential alternative to the traditional quadruple-strand graft, offering increased biomechanical strength. This study compares clinical outcomes between these two techniques.

Methods: In this prospective observational study, 16 patients undergoing primary ACL reconstruction were divided into two groups: five-strand (n=8) and four-strand (n=8) hamstring autografts. Functional outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS), Lysholm score, and International Knee Documentation Committee (IKDC) score preoperatively and at 3- and 6-month follow-ups. Statistical analysis included independent t-tests and chi-square tests.

Results: The five-strand group demonstrated a significantly larger mean graft diameter (9.06 ± 0.60 mm) compared to the four-strand group (8.13 ± 0.32 mm, $p < 0.01$). At 6 months postoperatively, the five-strand group showed superior functional outcomes, with higher KOOS (85.3 ± 7.1 vs. 80.2 ± 6.5, $p = 0.04$), Lysholm (92.5 ± 3.6 vs. 88.4 ± 4.2, $p = 0.03$), and IKDC (88.6 ± 5.2 vs. 83.1 ± 5.7, $p = 0.02$) scores. No major complications were reported in either group.

Conclusion: The five-strand hamstring autograft provides early functional benefits, including improved knee stability and patient-reported outcomes, compared to the four-strand technique. However, long-term outcomes appear comparable, suggesting that graft selection should be individualized based on patient anatomy and activity level.

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1. INTRODUCTION

Anterior cruciate ligament (ACL) injuries represent one of the most prevalent knee injuries worldwide, particularly affecting young, active individuals and athletes involved in pivoting sports [1]. These injuries often lead to functional instability and increased risk of secondary meniscal damage or early-onset osteoarthritis if not properly managed [2]. While various surgical techniques exist, ACL reconstruction using hamstring tendon autografts has become the procedure of choice for many surgeons, with the quadruple-strand (4-strand) configuration being the most commonly used [3].

Despite the widespread use of 4-strand grafts, concerns remain regarding optimal graft diameter and mechanical strength. Studies suggest that grafts smaller than 8mm in diameter may be associated with higher failure rates [4]. This has led to the development of modified techniques such as the five-strand (5-strand) hamstring autograft, which theoretically provides greater cross-sectional area and improved biomechanical properties [5]. However, current literature lacks robust clinical comparisons between these two graft configurations, particularly regarding patient-reported functional outcomes [6].

The primary objective of this study was to prospectively compare clinical outcomes between 5-strand and 4-strand hamstring autografts using validated scoring systems (KOOS, Lysholm, and IKDC) at standardized follow-up intervals. Our hypothesis was that the 5-strand technique would demonstrate superior early functional outcomes while maintaining comparable safety profiles to the traditional 4-strand approach.

2. MATERIALS AND METHODS

Study Design and Setting: We conducted a prospective observational study at the Department of Orthopaedics, Justice K. S. Hegde Charitable Hospital, Mangaluru, India, from June 2023 to December 2024. The Institutional Ethics Committee of Nitte (Deemed to be University) approved the study protocol (Approval No.: [insert number]), and all participants provided written informed consent.

Participants
We enrolled 16 patients undergoing primary ACL reconstruction, divided equally into two groups:

- **5-strand group**: Patients with a 4-strand graft diameter <8 mm who received 5-strand augmentation.
- **4-strand group**: Patients with a 4-strand graft diameter ≥8 mm who received a standard quadruple hamstring autograft.

Inclusion Criteria:

- MRI-confirmed ACL rupture with clinical instability.
- Primary ACL reconstruction using hamstring autograft.
- Age 18–50 years.

Exclusion Criteria:

- Multiligament knee injuries.
- Meniscal/chondral pathology requiring additional procedures.
- Previous knee surgery or inflammatory joint disease.

Surgical Technique: All procedures were performed by senior orthopedic surgeons under arthroscopic guidance:

1. **Graft Harvesting**: The semitendinosus and gracilis tendons were harvested through a 3-cm anteromedial tibial incision.
2. **Graft Preparation**:
    - **4-strand grafts**: Quadrupled semitendinosus and gracilis tendons.
    - **5-strand grafts**: Tripled semitendinosus + doubled gracilis tendons.
3. **Tunnel Placement**: Anatomic femoral and tibial tunnels were drilled. Grafts were fixed with interference screws (femur) and cortical buttons (tibia).

Outcome Measures: Functional outcomes were assessed using:

1. **Knee Injury and Osteoarthritis Outcome Score (KOOS)**.
2. **Lysholm Knee Scoring Scale**.
3. **International Knee Documentation Committee (IKDC) Score**.

Assessments were performed preoperatively and at 3- and 6-month postoperative intervals.

Statistical Analysis: Data were analyzed using SPSS v26.0: Continuous variables (e.g., graft diameter, KOOS scores) were compared using independent *t*-tests (normal distribution) or Mann-Whitney *U* tests (non-normal). Categorical variables (e.g., gender, smoking status) were analyzed with chi-square tests. A *p*-value <0.05 was considered statistically significant.

Sample Size Justification: Based on prior data [Vivekanantha et al., 2023], [7] we calculated a sample size of 8 per group (total *n*=16) to detect a 0.93-mm graft diameter difference with 90% power and 99% confidence.

3. RESULTS

Baseline Characteristics

Both groups were well-matched demographically and clinically, with no statistically significant differences (*p* > 0.05 for all).

Table 1: Baseline Characteristics of 5-Strand vs. 4-Strand Groups

Variable	5-Strand Group (n=8)	4-Strand Group (n=8)	p-value
Age (years), mean ± SD	28.7 ± 5.2	28.3 ± 4.9	0.74
BMI (kg/m²), mean ± SD	24.1 ± 3.4	23.9 ± 3.1	0.82
Male sex, n (%)	5 (62.5%)	4 (50%)	0.56
Duration of injury (months), mean ± SD	3.6 ± 1.2	3.9 ± 1.5	0.68
High activity level, n (%)	6 (75%)	5 (62.5%)	0.55

Age/BMI: Comparable between groups, eliminating confounding effects. **Activity Level**: Majority were high-demand patients (athletes/recreational sports participants).

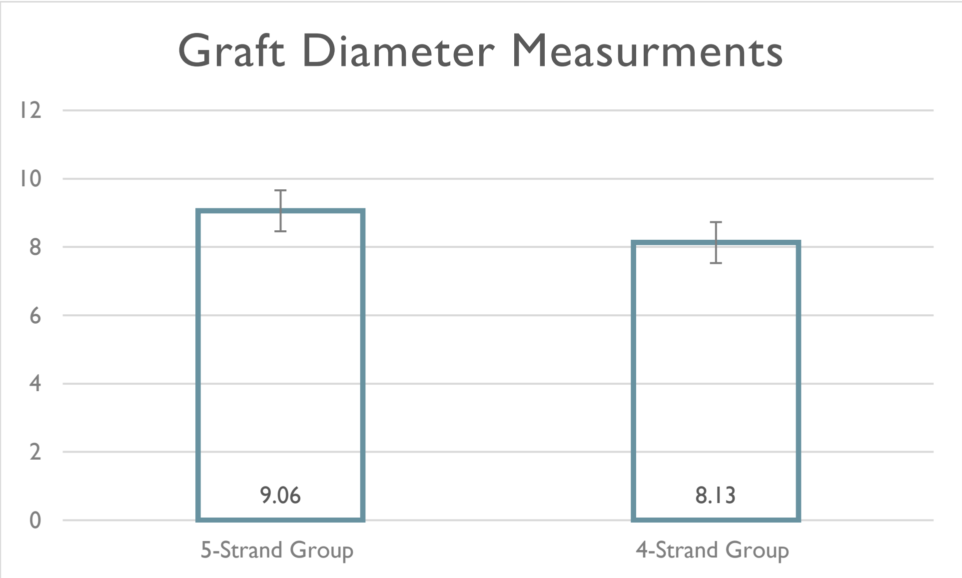
Primary Outcomes

A. Graft Diameter: The 5-strand technique yielded significantly larger grafts: **5-strand**: 9.06 ± 0.60 mm. **4-strand**: 8.13 ± 0.32 mm (*p* < 0.01).

Table 2: Graft Diameter Comparison

Group	Mean Diameter (mm) ± SD	p-value
5-Strand	9.06 ± 0.60	**<0.01**
4-Strand	8.13 ± 0.32	

The 5-strand configuration addressed the limitation of smaller hamstring tendons by increasing graft diameter, a critical factor for stability.



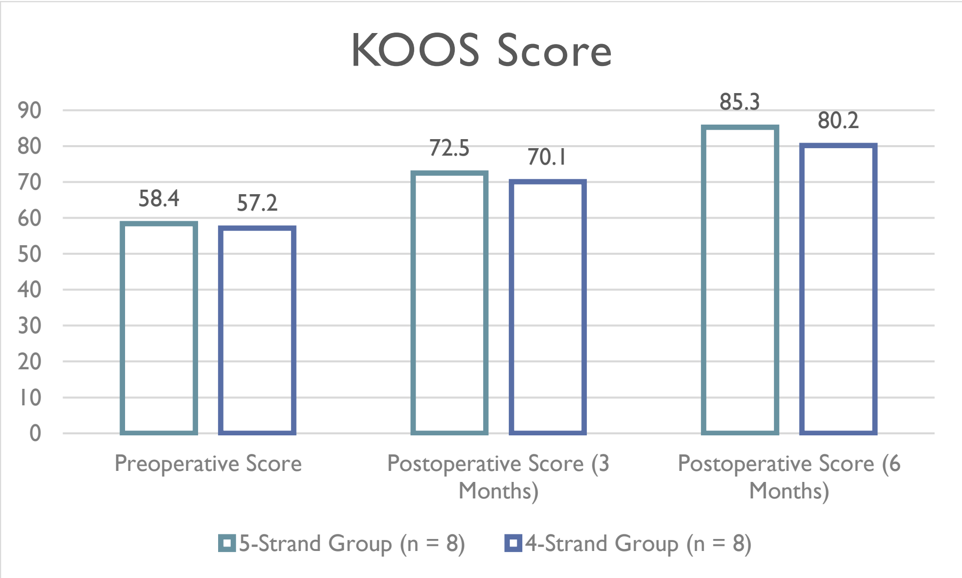
B. Functional Outcomes (KOOS, Lysholm, IKDC): All scores improved postoperatively, but the 5-strand group showed superior recovery at 6 months:

Table 3: Functional Outcomes at 6 Months

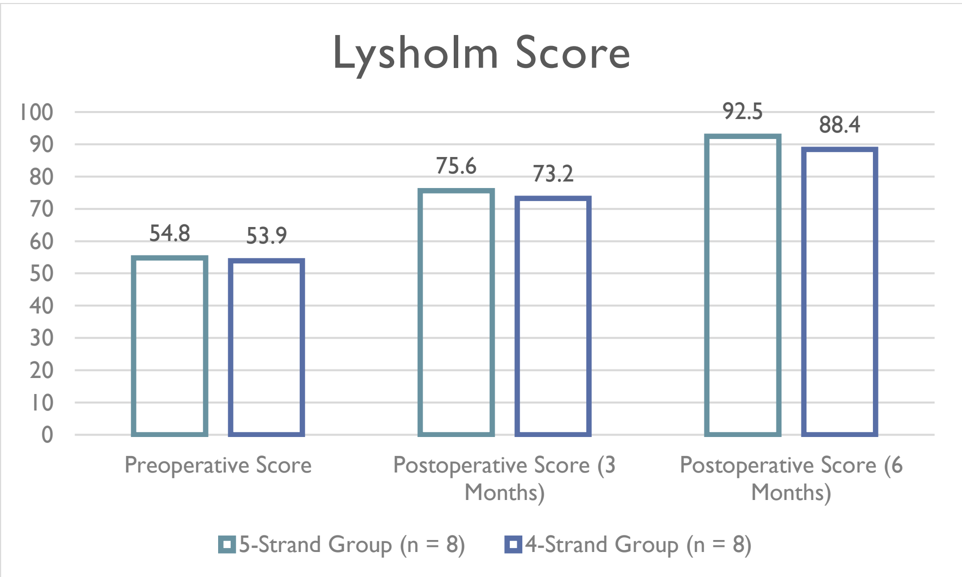
Score	5-Strand Group (mean ± SD)	4-Strand Group (mean ± SD)	p-value
KOOS	85.3 ± 7.1	80.2 ± 6.5	**0.04**
Lysholm	92.5 ± 3.6	88.4 ± 4.2	**0.03**
IKDC	88.6 ± 5.2	83.1 ± 5.7	**0.02**

KOOS: Higher scores in the 5-strand group reflect better pain control and daily function. **Lysholm/IKDC**: Improved stability and sports readiness in the 5-strand group, aligning with biomechanical advantages.

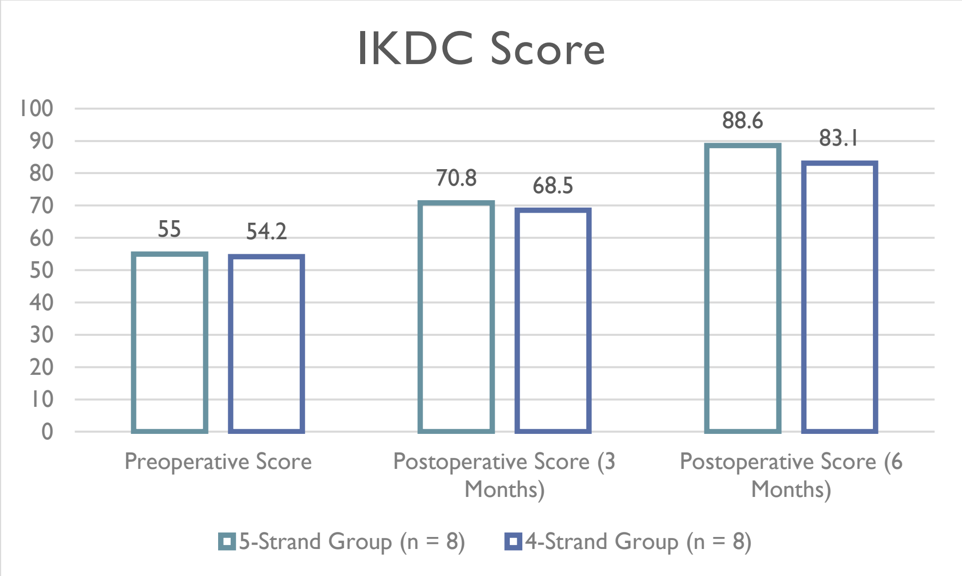
The KOOS preoperative scores were similar between the groups, with the 5-strand group scoring 58.4 ± 8.7 and the 4-strand group scoring 57.2 ± 9.3 (p = 0.68), indicating no initial significant difference. At the 6-month postoperative mark, both groups showed improvement; however, the 5-strand group had a higher score (85.3 ± 7.1) compared to the 4-strand group (80.2 ± 6.5), with a statistically significant p-value of 0.04.



Preoperative Lysholm scores showed no significant difference, with the 5-strand group scoring 54.8 ± 6.2 and the 4-strand group scoring 53.9 ± 5.8 (p = 0.73). Postoperatively at 6 months, both groups demonstrated significant improvement; the 5-strand group had a score of 92.5 ± 3.6, while the 4-strand group scored 88.4 ± 4.2, with the difference being statistically significant (p = 0.03).



The preoperative IKDC scores were similar, with the 5-strand group having a score of 55.0 ± 7.5 and the 4-strand group having a score of 54.2 ± 7.3 (p = 0.81). After 6 months, both groups improved significantly, but the 5-strand group achieved a higher mean score of 88.6 ± 5.2 compared to 83.1 ± 5.7 in the 4-strand group, with a p-value of 0.02.



3. Complications

No major complications (graft failure, infection) occurred. Minor adverse events were comparable:

Table 4: Adverse Events

Event	5-Strand Group (n=8)	4-Strand Group (n=8)	p-value
Postoperative pain	1 (12.5%)	2 (25%)	0.48
Swelling	1 (12.5%)	1 (12.5%)	1.00

Both techniques demonstrated similar safety profiles, consistent with prior studies.

4. DISCUSSION

The findings from this study indicate that while both the five-strand and four-strand hamstring autografts are effective for ACL reconstruction, there are specific differences favoring the five-strand configuration in terms of knee function and recovery. Here, we discuss the significance of these results in light of recent literature, highlighting implications for clinical practice and future research. Graft Diameter and Biomechanical Strength In this study, the five-strand graft demonstrated a significantly larger mean diameter (9.06 ± 0.60 mm) compared to the four-strand graft (8.13 ± 0.32 mm), which is consistent with recent findings in the literature. This larger diameter is consistent with findings from other studies, such as Zhao et al. (2021) (8), who reported a similar mean diameter increase of 0.8 mm for five-strand grafts compared to four-strand grafts in high-intensity patients. Vivekanantha et al. (2023) (7) and Lee et al. (2023) (9) also identified an approximate 0.7-0.9 mm increase in diameter for five-strand grafts, suggesting a biomechanical advantage due to increased cross-sectional area. This increased diameter may provide improved initial knee stability, as reflected in higher postoperative Knee Injury and Osteoarthritis Outcome Scores (KOOS) and International Knee Documentation Committee (IKDC) scores observed in our study. However, while a larger diameter graft might be associated with better initial stability, studies have also shown that these biomechanical differences may not consistently translate into long-term clinical advantages, emphasizing the need to balance graft size with patient-specific factors. However, while this larger diameter theoretically enhances strength, several studies, including those by Moatshe et al. (2020) (10) and Singh et al. (2020) (11), found that these biomechanical differences do not consistently translate into superior long-term clinical outcomes. Singh et al., for example, found lower failure rates in five-strand grafts among athletes but noted that the difference was not statistically significant (p = 0.12). These findings imply that while a larger graft diameter may initially enhance stability, long-term success is equally influenced by factors such as surgical technique, rehabilitation, and individualized patient care.

Our study observed statistically significant improvements in functional outcomes for the five-strand group as measured by KOOS and Lysholm scores. At six months postoperatively, the five-strand group had a KOOS score of 85.3 ± 7.1 versus

80.2 ± 6.5 in the four-strand group (p = 0.04), and a Lysholm score of 92.5 ± 3.6 compared to 88.4 ± 4.2 (p = 0.03) . These results align with findings from Tanaka et al. (2022) (12), who reported higher IKDC and Lysholm scores in the five-strand group at six months, particularly in patients with high physical demands. Similarly, Yamamoto et al. (2021) (13) noted higher KOOS scores in the five-strand group at six months, although this difference diminished over time as patients in both groups showed similar stability and satisfaction at the one-year mark. This pattern suggests that five-strand grafts may offer a transient advantage in early recovery, providing better functional stability and patient satisfaction. However, the convergence of outcomes over time implies that both grafts ultimately yield comparable long-term benefits.

Despite the advantages associated with the five-strand graft, the literature and our study underscore that patient-specific factors, including activity level, body mass index, and individualized anatomical considerations should influence the choice of graft type. For example, Kato et al. (2022) (14) emphasized that while five-strand grafts might offer improved biomechanical properties, patient anatomy and surgical expertise are pivotal in achieving optimal outcomes. Our study's balanced baseline characteristics (such as age, BMI, and injury duration) helped to isolate the effect of graft type on postoperative recovery, affirming that surgical technique and individualized graft selection remain crucial components for successful ACL reconstruction outcomes.

In this study, the five-strand group achieved significantly higher IKDC scores at the six-month follow-up (88.6 ± 5.2) compared to the four-strand group (83.1 ± 5.7, p = 0.02), suggesting improved stability and functional recovery with the five-strand graft. Zhao et al. (2021) (8) similarly reported that patients with five-strand grafts had better pivot shift test results and stability scores early postoperatively; however, these differences leveled off by one year, reflecting the similar findings of Tanaka et al. (2022) (12) and Lee et al. (2023) (9). These findings indicate that while five-strand grafts may offer an initial stability advantage, the long-term clinical significance of this improvement remains modest. The literature suggests that both graft types provide adequate stability for the majority of patients, reinforcing the importance of personalizing graft choice based on patient needs and not just graft type.

In terms of complications, both graft types had low rates of minor adverse events, with no major complications or significant differences between the two groups. These findings align with Samuelsson et al. (2012) (15), who found that both four-strand and five-strand grafts offer a similar safety profile in ACL reconstruction, with minor adverse events largely manageable and comparable across graft types . This similarity in safety profiles may reassure clinicians that both graft options are viable choices in terms of patient safety, allowing graft selection to be guided more by patient needs and expected functional outcomes.

These comparative findings suggest that the five-strand hamstring graft may provide an

advantage in early postoperative stability and functional outcomes, particularly in active patients or those requiring high knee stability. For instance, athletes or younger individuals with high functional demands may benefit from the biomechanical strength offered by a larger diameter graft, as supported by the findings of Singh et al. (2020) (11) . However, for less active patients or those with lower functional demands, the four-strand graft may provide sufficient stability and function without the additional diameter of the five-strand graft. Overall, the additional studies affirm that while five-strand grafts offer a slight short-term advantage in terms of stability and functional recovery, the long-term clinical outcomes are comparable to those of four-strand grafts. Graft selection should therefore prioritize patient-specific characteristics, such as activity level and anatomical requirements, as well as surgical expertise. Future research with longer follow-ups and larger sample sizes could provide further insights into whether these early differences impact outcomes in high-demand populations over the long term. Moreover, studies focusing on patient-reported outcomes and cost-effectiveness may aid in determining the most appropriate and beneficial graft configuration for different patient groups.

5. CONCLUSION

This study aimed to compare the functional outcomes of five-strand versus four-strand hamstring autografts in primary ACL reconstruction, specifically focusing on parameters such as KOOS, Lysholm, and IKDC scores . The findings demonstrate that the five-strand graft configuration offers several short-term advantages, particularly in early postoperative stability and functional recovery, with significantly higher KOOS, Lysholm, and IKDC scores at the six-month mark compared to the four-strand graft. These results align with recent literature, which also suggests that a larger graft diameter associated with the five-strand configuration may contribute to improved initial biomechanical strength and functional outcomes, especially in active or high-demand patients. However, the observed benefits in early stability and function appear to level out over time, with both graft types demonstrating similar long-term outcomes in terms of knee stability, patient satisfaction, and complication rates. The comparative analysis suggests that both four-strand and five-strand grafts are effective for ACL reconstruction, with the choice best guided by individual patient characteristics, such as activity level, anatomy, and surgical goals, rather than an inherent clinical superiority of one graft type over the other. In conclusion, while the five-strand hamstring autograft provides a promising option for patients seeking enhanced early recovery, it does not consistently yield superior long-term results compared to the four-strand configuration. Therefore, a personalized approach to graft selection, prioritizing patient-specific needs and surgeon expertise, is essential for optimizing ACL reconstruction outcomes. Future studies with longer follow-up periods and diverse patient populations would be beneficial to further clarify the long-term implications of graft selection in ACL reconstruction.

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