J Orthop Spine Trauma. 2025 December; 11(4): 163-9. DOI: 10.18502/jost.v11i4.20287

Research Article

A Comparative Study of Braided versus Standard Preparation of Autologous Hamstring Graft in Anterior Cruciate Ligament Reconstruction

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Received: 07 May 2025; **Revised:** 12 July 2025; **Accepted:** 17 August 2025

Abstract

Background: Anterior cruciate ligament (ACL) reconstruction commonly employs autologous hamstring grafts, with various techniques used for graft preparation. Standard 4-strand grafts are widely accepted; however, braided grafts have been proposed to offer improved biomechanical properties and graft fixation. This study aims to compare the clinical and functional outcomes of braided versus standard hamstring graft preparations in ACL reconstruction.
Methods: In this prospective randomized study, 171 patients undergoing primary ACL reconstruction were assigned to two groups: group A (standard graft, n = 92) and group B (braided graft, n = 79). Intraoperative data such as graft length and diameter were recorded. Clinical and functional outcomes were evaluated using International Knee Documentation Committee (IKDC) and Lysholm scores and knee range of motion (ROM) at 2 weeks, 6 weeks, 3 months, and 6 months postoperatively.
Results: The braided graft group demonstrated a larger mean graft diameter (P = 0.492) but decreased graft length (P = 0.028). During follow-ups till 6 months, both groups showed progressive improvement but no significant difference between the two groups with respect to knee ROM, IKDC, or Lysholm scores. Difference in complications was statistically insignificant.
Conclusion: The study suggests that both standard and braided hamstring grafts are effective options for ACL reconstruction, yielding comparable short-term clinical outcomes. However, the braided technique demonstrates potential advantages in terms of increased graft thickness and uniform fixation. While these findings are promising, further in vivo studies and long-term clinical trials are necessary to validate the superiority of the braided graft technique in ACL reconstruction.

Keywords: Anterior Cruciate Ligament Reconstruction; Hamstring Tendons; Graft

Citation: Kothiyal P, Vij K, Gupta M. **A Comparative Study of Braided versus Standard Preparation of Autologous Hamstring Graft in Anterior Cruciate Ligament Reconstruction.** *J Orthop Spine Trauma* 2025; 11(4): 163-9.

Background

Anterior cruciate ligament (ACL) injury is one of the most common sports injuries with a reported incidence rate between 36.9 and 60.9 per 100000 persons per year (1) which is growing. It is more common in adolescents and young adults, with the maximum recorded incidence being between the ages of 15 and 34 (2). ACL tears are commonly due to non-contact injury. The mechanism of injury is usually a combination of knee rotation and flexion/hyperextension. However, nowadays road traffic accidents (RTAs) are also responsible for a large number of cases. Presentation includes history of pain and instability, which may be accompanied with locking in case of meniscal involvement; some patients report hearing a 'pop' sound at time of injury. Clinical tests like anterior drawer, Lachman test, and pivot shift test can help detect ACL injury which can be confirmed with magnetic resonance imaging (MRI) scan. Treatment can be surgical or conservative depending on various factors like age, physical activity demand, symptoms, or grade of tear. Conservative management includes supportive bracing, physiotherapy, and activity modification. ACL reconstruction is the gold standard surgical treatment for physically-active patients with symptoms of knee instability attributed to the ACL injury, patients with multiple knee ligament injuries, and those who remain symptomatic after a trial of non-operative treatment (Paschos and Howell) (3). Many factors play an important role in performing an adequate ACL reconstruction: tunnel positioning, graft selection, diameter, fixation, length, and configuration (4-11).

The choice of graft in ACL reconstruction is still debatable (12). This is a crucial choice that needs to be made while taking into account a variety of aspects, including the surgeon's preferences, the needs and expectations of the patient, the kind and level of sports being played, and graft specifications (5, 13-15). The autologous hamstring graft is commonly used because it offers accessibility and ease of harvest, soft tissue tunnel passage, comparable strength to original ACL, and the ability to customize the length and diameter of the graft (3, 6, 8-10). These benefits imply that it could potentially overcome past disadvantages of ACL reconstruction, as increased graft diameters have been associated with better success rates and long-term outcomes (12).

There are several graft preparation techniques for hamstring autograft (like two-strand, three-strand, four-strand, six-strand, eight-strand, and braiding method of graft preparation, with varied final diameters, lengths, and configurations) (6-8, 10, 11). For an ACL graft to be considered optimal, it must have a strength that is similar to or exceeds the original ACL. One such procedure is the braided graft, which can be created by braiding the semitendinosus (ST) and gracilis (GC) tendons together. Advantages of braided hamstring grafting include thicker graft (approximately 1mm increase), ribbon like and braided shape that mimic the original ACL theoretically increasing biomechanical strength, easier and stronger tibial fixation thus potentially decreasing graft rupture, and not requiring mastering different hamstring

configuration techniques. A disadvantage is that the graft could be shorter by approximately 5-10 mm in length (15). This study was conducted in Shri Mahant Indiresh Hospital, Dehradun, India, between 2022-2024 amongst patients presenting with ACL tear +/- meniscus injury who were managed by arthroscopic ACL reconstruction (standard and braided preparation) +/- partial meniscectomy and were put under ACL rehabilitation, followed up at 2 weeks, 1.5 months, 3 months, and 6 months and assessed on the basis of International Knee Documentation Committee (IKDC) score, Lysholm score, and knee range of motion (ROM).

Methods

Patients presenting to the orthopedics department of Shri Mahant Indiresh Hospital who were diagnosed clinically as ACL tear and confirmed with MRI were divided into 2 groups. One group was managed with arthroscopic ACL reconstruction using standard preparation of autologous hamstring graft, and the second group using braided preparation of autologous hamstring graft.

Pre-operatively, patient was admitted 1-2 days before the planned surgery and was clinically assessed with history and examination. Pre-operative investigations complete blood count (CBC), renal function test (RFT), prothrombin time/international normalized ratio (PT/INR), hepatitis B, C, and HIV (HHH) were performed, and pre-anesthetic check-up was done.

Surgical Technique

Graft Harvest: ST and GC tendons were harvested using the standard harvesting technique.

Standard Graft Preparation: The removal of the muscular tissue of each tendon was done. The tendon ends were trimmed to achieve uniform size. A whipstitch was placed at both ends of the tendons. Around 3-4 cm of both ends of the tendon were stitched together. The two tendons were looped over an umbilical tape.

Figure 1. Doubled gracilis (GC) and doubled semitendinosus (ST), four-strand hamstring tendon graft

The loop of the four-strand graft was subjected to pre-tensioning by applying a pressure of about 15 pounds for around fifteen minutes (Figure 1) to create final ACL graft (Figure 2).

Figure 2. Standard hamstring graft preparation

Braided Graft Preparation (ST + GC): Both tendons were loaded to create a 4-strand graft with 2 tendons (GC and ST). The four free ends were stitched with a non-absorbable suture, and the four-strand graft was stitched together 1 cm distally from the cortical suspensory adjustable-length device to reinforce and keep the same length to each free end of each tendon. Proper measurements (diameter and length) were taken before and after preparing the hamstring braid graft configuration. Hamstring braid graft preparation started from right to left; the distal end of the graft that was more on the right was passed above the distal end on its left, then below the next end on the left, and finally above to the last of the four ends, which initially was located on the left corner. This sequence was repeated until no more distally remaining tendon was available. At the end of the hamstring braid graft configuration, each suture pair (the same tendon) was hand stitched together, and final measurements were done (Figure 3).

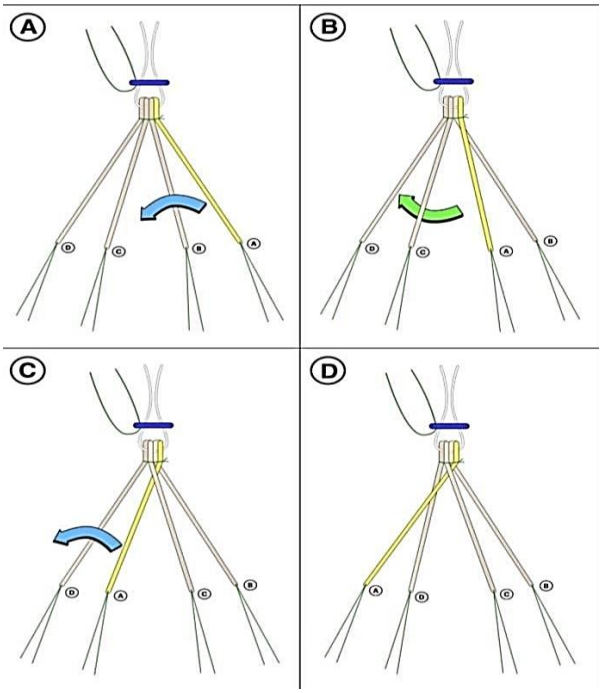

Figure 3. Representation of the technique for braiding the graft. Strand A is looped over strand B, under C then over D, and then the process is repeated

Figures 4 and 5 show case illustrations depicting the intraoperative techniques of braided graft preparation and reconstruction, with intra-operative visualization via arthroscopy and C-arm imaging (Figure 6) of resultant graft fixed with endobutton.

Figure 4. Case demonstrating braiding technique

Figure 5. Braided graft prepared

Postoperatively, weight bearing was started from postoperative day one (POD 1), with focus on quadriceps and hamstring strengthening and gradual increase in knee ROM.

The functional outcome was assessed by IKDC score, Lysholm Knee Scoring Scale, and ROM evaluation.

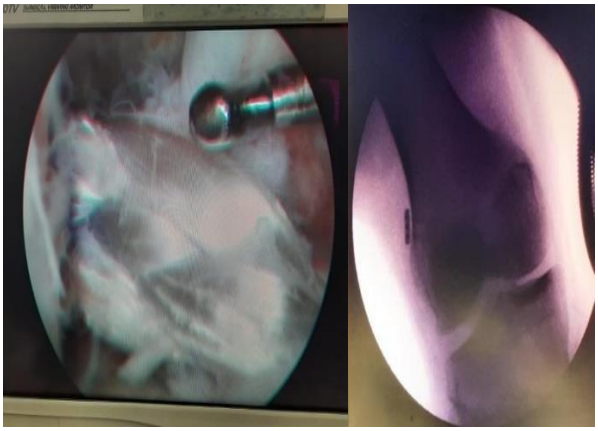

Figure 6. Intraoperative C-arm view after graft fixation showing endobutton (left), arthroscopic visualization of braided graft (right)

Follow-Up

Assessment in 2nd week post-operatively:

- Clinical assessment of pain, ROM, and stiffness
- Condition of surgical site

Assessment at 6 weeks, 12 weeks, 6 months post-operatively

- Functional scoring, ROM at knee joint
- Assessment of any complications

Results

For our study, conducted in Department of Orthopedics in Shri Mahant Indiresh Hospital, Dehradun, from July 2021 to July 2024, 333 patients with internal derangement of knee (IDK) were assessed out of which 21 patients had multiligamentous injury [ACL and posterior cruciate ligament (PCL) tear, ACL and medial collateral ligament (MCL) tear], 27 patients had ACL avulsion, 63 patients underwent meniscus repair, 30 patients had associated fractures in affected lower limb or had history of arthroscopic surgery in past, and 21 post-operative ACL patients were lost for follow-up. Hence, remaining 171 patients were included in the study.

The table 1 presents data comparing two groups, the standard group and the braided group, across different age categories. Each group was subdivided into three age groups: 18-30, 31-42, and 43-55 years. A chi-square test was conducted to assess whether there was a significant difference between the two groups across the various age categories.

Table 1. Age distribution of patients

Age group (year)	Standard group (No. of cases)	Braided group (No. of cases)
18-30	58	42
31-42	28	29
43-55	6	8
Total	92	79

The table 2 shows comparison between the standard and braided groups and it reveals slight variations in sex distribution. In the standard group, women constituted 35.8% of the cases, whereas in the braided group, they made up 43%. Conversely, men represented 64.1% and 56.9% of the standard and braided groups, respectively.

Table 2. Comparison of gender between the two groups

Sex	Standard group (No. of cases)	Braided group (No. of cases)	Total
Women	33	34	67
Men	59	45	104
Total	92	79	171

The table 3 presents a comparison between the standard and braided groups concerning the mode of injury, categorized into four types: fall from height, RTA, slip and fall, and sports-related injuries.

Comparison of the measurements of graft diameter in the two groups revealed that the mean of final graft diameter for the standard group was 7.69 mm with a standard deviation (SD) of 0.74 mm, while the braided group had a mean of 7.87 mm with an SD of 0.83 mm. The statistical analysis, indicated by the Z-value of -0.688, suggests that the observed difference in final graft diameter between the two groups was not statistically significant (P = 0.492).

Table 3. Mode of injury

		Standard group (No. of cases)	Braided group (No. of cases)	Total percentage for both groups
Mode of injury	Fall from height	3	0	1.7
	RTA	33	27	33.1
	Slip and fall	18	25	25.1
	Sports	38	27	38.1
Total		92	79	100

RTA: Road traffic accident

Table 4. Comparison of measurements related to graft length between the standard group and the braided group

	Standard group	Braided group	Z	P-value
	Mean ± SD	Mean ± SD		
Harvested ST graft length (mm)	250.29 ± 22.63	260.87 ± 18.57	-1.857	0.069
Harvested GC length (mm)	207.65 ± 19.32	211.30 ± 10.68	-0.825	0.413
Pre-braid graft length (mm)	.	98.04 ± 12.50		
Final graft length (mm)	94.85 ± 10.84	87.83 ± 12.51	2.257	0.028

ST: Semitendinosus; GC: Gracilis; SD: Standard deviation

The data provided by table 4 compares measurements related to graft length between the standard group and the braided group. In the harvested ST graft length, the braided group showed a slightly higher mean compared to the standard group although this difference was not statistically significant (Z = -1.857, P = 0.069). Similarly, in the harvested GC length, no significant difference was found between the two groups (Z = -0.825, P = 0.413). The pre-braid graft length for the braided group showed a mean of 98.04 mm. However, in the final graft length, a notable difference emerged, with the standard group exhibiting a mean of 94.85 mm and the braided group showing a mean of 87.83 mm. This difference was statistically significant (Z = 2.257, P = 0.028), indicating that the braided technique may have influenced final graft length.

The comparison in table 5 provides insights into the mean and SD of knee ROM in degrees for both the standard and braided groups across four distinct time intervals post-treatment.

Table 5. Comparison of the mean and standard deviation (SD) of knee range of motion (ROM)

Knee ROM	Standard group	Braided group	Z	P-value
	Mean ± SD	Mean ± SD		
2 weeks	85.59 ± 15.80	82.17 ± 12.78	-0.612	0.540
1.5 months	115.88 ± 10.76	115.43 ± 9.64	-0.292	0.771
3 months	126.62 ± 9.43	126.96 ± 5.98	-0.477	0.633
6 months	131.03 ± 4.89	131.09 ± 4.76	-0.026	0.979

ROM: Range of motion; SD: Standard deviation

Figure 7 depicts mean post-operative knee ROM of both groups at follow-ups.

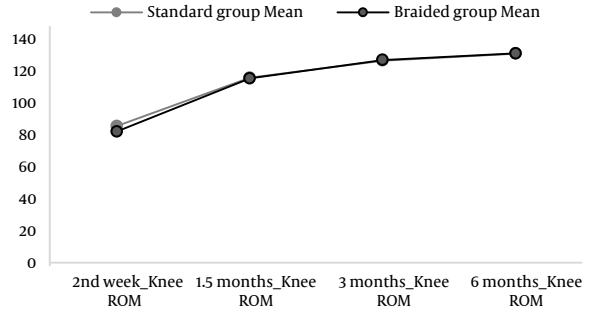

Figure 7. The graphical depiction providing insights into the mean of knee range of motion (ROM)

Functional scores of IKDC and Lysholm have been compared at subsequent follow-ups in table 6 which show subsequent increase in both groups, but the difference between the two groups was statistically insignificant.

Table 6. Comparison of International Knee Documentation Committee (IKDC) and Lysholm scores between the standard and braided groups

	Standard group	Braided group	Z	P-value
	Mean ± SD	Mean ± SD		
2 weeks-IKDC	26.74 ± 7.76	24.57 ± 6.88	-1.099	0.272
1.5 months-IKDC	47.34 ± 7.55	44.83 ± 9.57	-0.822	0.411
3 months-IKDC	62.51 ± 9.78	58.96 ± 8.14	-1.611	0.107
6 months-IKDC	76.64 ± 11.38	71.94 ± 10.10	-1.717	0.086
2 weeks-Lysholm	44.50 ± 10.55	39.87 ± 10.19	-1.460	0.144
1.5 months-Lysholm	68.79 ± 9.58	66.87 ± 8.95	-0.646	0.518
3 months-Lysholm	82.00 ± 11.15	80.09 ± 6.60	-1.397	0.163
6 months-Lysholm	89.94 ± 7.87	88.30 ± 5.18	-1.334	0.182

The mean values at follow-ups have been represented in figures 8 (IKDC) and 9 (Lysholm).

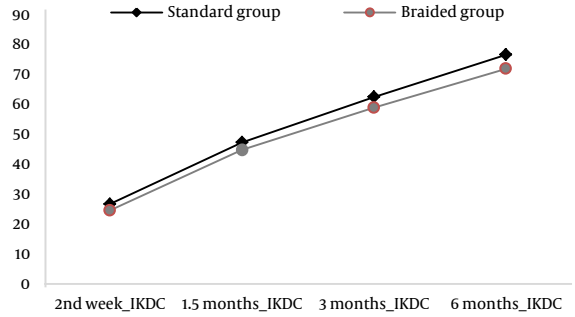

Figure 8. Comparison of International Knee Documentation Committee (IKDC) between the two groups

Complications

In the standard group, there were 88 cases (95.6%) without complications, while in the braided group, all 79 cases (100%) reported no complications.

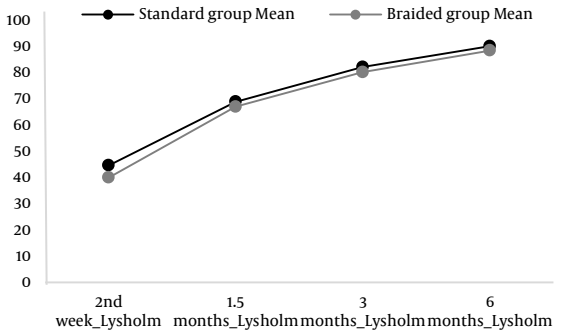

Figure 9. Comparison of Lysholm score between the two groups

Conversely, in terms of cases with complications, the standard group reported 4 cases (4.3%), whereas the braided group reported none (Table 7).

Table 7. Comparison of complication between the two groups

	Standard group	Braided group	Total	Chi-square value	P-value
	n (%)	n (%)			
Complications				2.910	0.140
No	88 (95.6)	79 (100)	167		
Yes	4 (4.3)	0 (0)	4		
Total	92 (100)	79 (100)	171		

A chi-square test was conducted to assess the association between complications and group type. The chi-square value was reported as 2.910, with a corresponding P-value of 0.140.

With a P-value of 0.140, which exceeds the common significance level of 0.05, there was no statistically significant difference in the occurrence of complications between the standard and braided groups.

All the complications that occurred in 4 cases had different reasons like history of repeated trauma after 2

months, history of slip and fall at 6 months, posterior horn of medial meniscus (MM) tear after 3 months, and surgical site infection (SSI).

Discussion

The ACL is an important restraint to tibial rotation and anterior tibial translation and aids in the overall stability of the knee. ACL is commonly injured in knee injuries; hence, many ACL reconstructions are done nowadays, the aim of which is to allow the patient to return to routine activity preventing further meniscal damage and providing normal function of knee.

The graft choice has often been a topic of debate. An ideal graft should have same biomechanical properties, promote rapid incorporation, and have minimum donor site morbidity. The hamstring graft, bone-patellar tendon-bone (BPTB) graft, and peroneus graft have been increasingly used in past few years. The advantages of arthroscopic ACL reconstruction using hamstring graft include reduced incidence of anterior knee pain, decreased surgical site morbidity, and decreased occurrence of patellofemoral adhesions.

A meta-analysis by Samuelsen et al. involving a large cohort of patients reported that hamstring autografts had a higher failure rate compared to BPTB autografts (12). Conversely, Dai et al. found superior anteroposterior (AP) stability with six-strand hamstring allografts compared to BPTB allografts. These findings support the hypothesis that a stronger and more robust hamstring graft configuration may lead to better stability and potentially improved functional outcomes in ACL reconstruction (16).

Bourke et al. studied 143 patients and found that 94% had good or excellent Lysholm scores at the 1-year follow-up. Additionally, 67% of participants returned to their pre-injury level, while 33% did not (17). Khan et al. emphasized that favorable outcomes from ACL reconstruction using a hamstring graft depended on the timing of the surgery, the thickness of the graft, and an effective post-operative physiotherapy protocol (18). Williams et al. reported a significant improvement in mean scores post-operatively, a statistically significant change (19). This study supports the finding that ACL reconstruction using hamstring autografts leads to favorable outcomes.

These studies collectively highlight the effectiveness of hamstring grafts in ACL reconstruction, demonstrating comparable or superior outcomes to other graft types, particularly in terms of patient comfort and functional recovery.

Consequently, there is ongoing research focused on identifying technical enhancements that could potentially translate into functional improvements for patients undergoing ACL reconstruction. This ongoing exploration underscores the persistent efforts within the medical community to optimize outcomes and enhance patient care in ACL reconstruction procedures (20). A study by Samitier and Vinagre suggests that braided preparation of a hamstring graft could be an easy-to-prepare, reliable, and reproducible graft configuration that provides a stronger and more uniform hamstring graft that can be used in primary and revision ACL reconstruction (15). Its potential limitations include shortening of graft length by approx. 10 mm and lack of biomechanical results to corroborate clinical findings; the presumed increased strength and resistance of braided thicker graft could have a counter effect to the expected one and make it too rigid, and therefore cause an augmented risk of re-rupture in the mid-to-long term.

Our study assessed and compared the functional outcomes of two distinct graft preparation techniques: standard preparation utilizing autologous hamstring grafts versus a method involving braided hamstring graft preparation. By evaluating functional outcomes like length and diameter, as well as clinical parameters like ROM, stability, and patient-reported outcomes, our study sought to determine the potential differences in postoperative recovery and overall success between these two techniques.

This investigation holds significance as it could offer valuable insights into optimizing surgical technique for ACL reconstruction, ultimately contributing to improved patient outcomes and enhanced long-term joint function.

The mean age in the standard group of our study was 28.38 years while in the braided group, it was slightly higher at 29.87 years with an SD of 8.46.

A study by Sliepka et al. concluded that ACL reconstruction done in patients below 40 years of age had a better outcome (21).

Out of the total pool, 60.8% of patients were men and 39.1% were women, compared to study conducted by Bhardwaj et al. (22) that had 92% men. In their study, Wild et al. stated that girls involved in sports activity had 8 times more chance of suffering ACL injury than boys (23).

In our study, 38.1% of cases were of sports injuries. Chappell et al. suggested that ACL tears during sports activity were usually from non-contact sports, following which came RTAs (33%), slip and fall (25.1%), and fall from height (1.7%) as the modes of injury (24).

Most commonly encountered complaint in cases of ACL injury is that of pain and instability, with pain becoming less prominent in chronic cases. This could be accompanied by history of swelling, locking depending on chronicity of injury, and associated meniscus tear.

As also found in our study, majority of ACL cases have associated meniscal injuries. Depending on the type of tear, meniscal injury could be managed conservatively, repaired (preferred treatment if repair possible, especially in young active individuals), or partially excised. In our study, we have included cases where meniscal injury was managed conservatively or by partial meniscectomy in order to maintain uniform post-operative ACL rehabilitation. In a study conducted by Hagino et al., the incidence of meniscal tear associated with injury was higher in chronic cases (25). Timely ACL reconstruction is advised for prevention of secondary meniscal tears.

In our study, mean time since injury before reconstruction was 9.16 months for standard group and 10.3 months for braided group. These findings have been distorted due to 4 neglected cases which presented after more than 5 years; other than these 4, the mean time since injury came out to be 5.14 months. Spahn et al. in their study concluded that ACL injury was a significant factor for developing secondary knee osteoarthritis. The relative risk of osteoarthritis was doubled each year after ACL injury (26).

The mean graft diameter in the standard group was 7.69 mm, and in braided group 7.09 mm (pre-braid) to 7.87 mm (post-braid) demonstrating a mean increase of 0.78 mm, with a maximum of up to 1.5 mm increase seen. According to a study by Asif et al., minimum ACL graft diameter in Indian population should be more than 7 mm to prevent failures (27). Magnussen et al. conducted a study that found grafts with a diameter of 8 mm or less were significantly associated with higher rates of revision ACL surgery (28). The difference between the two studies

along with our study findings could indicate graft diameter difference in different races. The harvested ST and GC graft lengths compared between the two groups showed numerical difference but the P-value < 0.05 implies insignificance of the difference. Whereas the mean pre-braid and post-braid graft lengths were 98.04 and 87.83, respectively, i.e., a mean decrease of 10.21 mm with Z-value of 2.257 and P-value of 0.028 indicating significant change in the length due to braiding. This is in corroboration with the study conducted by Samitier and Vinagre (15) that found braiding to reduce graft length by approximately 10 mm.

Post-operative functional status was assessed based on various knee scores and knee ROM. In our study, except for the 4 cases with complications, increase in IKDC and Lysholm scores was seen along with knee ROM at subsequent follow-ups for which chi-square tests have been conducted to find association between the 2 groups. P-values > 0.05, along with Z scores, imply that no significant difference was found between the standard and braided preparation groups till 6 months post-operatively in all 3 parameters. Further long-term follow-ups may reveal differences between the 2 groups which could be in the form of more laxity in one group compared to the other.

The comparison of complications between the standard and braided groups following ACL reconstruction shows that in the standard group, the majority of cases, accounting for 95.6%, reported no complications, while all cases in the braided group, total 100%, were free of complications. Furthermore, specific complications such as repeated trauma after 2 months, slip and fall before the 4th visit, posterior horn of MM tear after 3 months, and SSI were exclusively observed in the standard group. The cases with repeated trauma showed drop in IKDC and Lysholm scores but were managed conservatively whereas the case with SSI required multiple wound debridements and eventually implant removal following which patient has been asymptomatic. Point to be noted is that repeated injury could be an adverse event and may not be linked to the surgical outcome directly (e.g., laxity). However, no such complications were reported in the braided group. Statistical analysis showed that there was no significant difference in complication rates between the two groups, as indicated by a chi-square value of 2.91 and a P-value of 0.573.

At 6-month follow-up, better anterior translational control was found in the braided group compared to the standard group but this finding could not be quantified due to unavailability of KT1000 arthrometer because of financial concern. Therefore, it is not a concrete finding yet. Less work has been done on ACL braided hamstring graft preparation, and hence needs further studies. Graft tensioning tests could further help arrive at a conclusion.

Limitations: Some limitations of the study were:

Small Patient Pool: ACL recovery depends on individual factors, like post-operative rehabilitation, which have individual variations due to difference in motivation and socioeconomic factors. This can interfere with the comparison between the two groups. Taking a larger patient sample will help overcome this.

Follow-Up Duration: Further long-term follow-ups may reveal difference between the 2 groups which may be in the form of difference in laxity or need for revision surgery.

Post-Operative Assessment: Post-operative laxity measurements were not taken due to unavailability of KT1000 arthrometer due to financial concern.

Conclusion

This study suggests that while both standard and braided hamstring grafts are effective for ACL reconstruction, the braided technique offers potential benefits in graft thickness and uniform fixation, possibly leading to stronger grafts with fewer complications. However, further research and in vivo studies are needed to confirm these findings and establish the long-term benefits of the braided technique.

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgements

We would like to express our sincere gratitude to the Department of Orthopedics at Shri Mahant Indiresh Hospital, for their continuous support and provision of resources throughout the course of this study. We are especially thankful to the surgical team and operating room staff for their assistance during data collection and graft preparation procedures. Finally, we extend our thanks to the patients who participated in this study for their trust and cooperation.

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