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Comparative Study Of Functional Outcome Of ACL Reconstruction With Arthroscopic Two Strands And Four Strands Hamstring Autograft

[1]Dr. M. Karthikeyan, [2]Dr. Muruga Valavan

[1]Ph.D (Research Scholar**),** Tamil Nadu Physical Education and Sports University, Chennai
[2]Professor cum Medical Officer, Tamil Nadu Physical Education and Sports University, Chennai

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Abstract
Background: Anterior cruciate ligament (ACL) injuries are commonly observed conditions presented in sports medicine, which often require surgical reconstruction. Implication of two-strand and four-strand hamstring autografts are commonly used for ACL reconstruction modality. However, concerning with impact on graft diameter and recovery rates is not well understood. The present study intends to explore on the functional outcomes of two-strand and four-strand hamstring grafts on the study population.
Methods: A total of 60 patients underwent ACL reconstruction using either a two-strand semitendinosus tendon graft (n=30) or a four-strand semitendinosus and gracilis tendon graft (n=30). Graft fixation was achieved using suspensory endobutton and interference screw techniques. Functional outcomes were determined using the Lysholm Scoring System, IKDC Subjective Scoring, and Knee Flexion and Extension Strength Testing were evaluated during the followup time frame of 20-months, with mean followup period of 12 months.
Results: Findings showcased no significant differences between both the groups concerning with functional outcomes namely- knee strength, range of motion, thigh girth, or Lysholm scoring. Patients who are consistently subjected to physiotherapy and yoga during rehabilitation phase had a faster recovery and earlier return to work when on comparison to that of those individuals who were inconsistent. Males have regained full strength and power in their injured site much more earlier compared to females. Four-strand hamstring grafts showcased slightly superior outcomes notably with respect to rotational stability, anterior stability, and early return to day-to-day activities when compared with two-strand grafts.
Conclusion: Both groups of the ACL autografts presented as a viable option for reconstruction, with no significant differences from the measured functional outcomes. Consistent physiotherapy and yoga during rehabilitation showed direct association with patients' faster recovery. Four-strand hamstring grafts may provide better advantages with regards to anterior stability, rotational stability, and early return for patients in performing their daily activities. These findings can inform surgical decision-making in ACL reconstruction.

Keywords ACL reconstruction, two-strand hamstring graft, four-strand hamstring graft, arthroscopy; sports medicine, physiotherapy.

Introduction

Anterior cruciate ligament (ACL) injuries can be attributed as one of the most commonest injuries presented in the field of orthopedics, especially the clinical presentation is quite prevalent among young and athletic populations [1]. The ACL functioning plays a pivotal role in maintaining stability of knee joint, and as a result of injured ACL site significantly impacts normal knee functioning and stability, resulting in pain, instability, and eventually causes limitations in performing normal day-to-day activities [1] [2]. In order for corrective intervention involves deploying surgical intervention which is quintessential for restoration of knee stability and functioning following ACL injury [3].

With regards to ACL reconstruction which is widely performed surgical procedure aimed in restoration of the injured knee [4]. Major considerations concerning ACL reconstruction is the choice of graft material utilized [5]. Autografts, which are harvested from the patient's own body, are preferred over allografts due to their superior outcomes in terms of patient-reported outcomes, decreased failure rates, and faster return to sport [5] [6]. Among autograft options, hamstring tendon autografts have become a popular choice for ACL reconstruction due to their favorable outcomes and lower risk of donor site morbidity compared to other graft options [7].

The hamstring tendons, comprising of semitendinosus and gracilis tendons are harvested either for two-strand or for the four-strand configuration in the reconstruction of ACL [7] [8] [9]. Since the autografts preferred on allografts as a result of the lesser likelihood of infection followed with facilitation of better host tissue incorporation in the grafted site. Among the

available options in autograft ACL reconstruction modality, application of hamstring tendon autografts gained much greater attention and popularity as a result of its availability, ease of harvest, and also presented greater likelihood of exhibiting favourable outcomes [8]. The semitendinosus and gracilis tendons are quite commonly utilized in ACL reconstruction, either via using individual tendonsor as combined graft [10]. One key whilst considering ACL reconstruction is primarily is its graft size [11]. Grafts with smaller diameter <8 mm reported with higher likelihood presentation of failure rates, especially among the younger patients [12]. Techniques that are essential for increasing the graft thickness, namely folding graft on itself, were developed for addressing this issue, especially for cases where hamstring tendons are insufficient [13]. The choice between a two-strand and four-strand hamstring autograft depends on several factors, including the patient's age, activity level, and anatomical considerations [14]. While both graft configurations have been used successfully in ACL reconstruction, there is limited clinical evidence comparing their functional outcomes [15]. This study aims to fill this gap by comparing the functional outcomes of ACL reconstruction using these two graft configurations. The objective of this study is to compare the functional outcomes of ACL reconstruction using two-strand and four-strand hamstring autografts. The choice of graft configuration is based on various factors, including surgeon preference, patient anatomy, and desired graft size and strength [16]. While both two-strand and four-strand hamstring autografts have been used successfully in ACL reconstruction, there is ongoing debate regarding which graft configuration yields superior functional outcomes [17].

Previous studies have primarily focused on biomechanical properties and graft strength, with limited clinical evidence comparing the functional outcomes of these graft configurations [18]. Therefore, this prospective study aims to compare the functional outcomes of ACL reconstruction using two-strand semitendinosus tendon grafts with those of four-strand semitendinosus and gracilis tendon grafts on the functional outcomes of ACL reconstruction using these graft configurations. The study evaluates on various outcome measures, including knee strength, range of motion, thigh girth, and patient-reported outcome scores. Additionally, the study intends to evaluate the impact of consistent physiotherapy and rehabilitation. Overall, this study aims to provide valuable insights into the optimal graft configuration and postoperative rehabilitation protocol for ACL reconstruction. The findings of this study have the potential to improve surgical decision-making and ultimately, patient outcomes following ACL reconstruction.

2. Materials & Methods

This prospective comparative study was conducted to evaluate the functional outcomes of ACL reconstruction using two-strand and four-strand hamstring autografts. The study protocol was approved by the institutional review board, and all patients provided informed consent before participation.

Patient Selection

A total of 30 patients with ACL injuries were included in the study. The patients were divided into two groups: the two-strand graft group (n=15) and the four-strand graft group (n=15). Inclusion criteria included a confirmed diagnosis of ACL injury based on physical examination and MRI findings, age between 18 and 50 years, and no history of previous knee surgeries or injuries.

Surgical Technique

All surgeries were performed arthroscopically by experienced orthopedic surgeons specialized in sports medicine. In the two-strand graft group, the semitendinosus tendon was harvested and doubled over to create a two-strand graft. In the four-strand graft group, both the semitendinosus and gracilis tendons were harvested and doubled over to create a four-strand graft. Graft fixation was achieved using a suspensory endobutton on the femoral side and an interference screw on the tibial side (See Figure 1).

Two-Strand Graft Preparation
With One Tendon (Either GC or ST). The tendon is loaded in a suspensory device with the middle portion of the tendon in the clamp (Fig 2; Video 1). The 2 free ends of the graft are folded on top of one another, and are stitched together with a nonabsorbable suture trying to equalize both the ends of the graft. The graft is whipstiched in the distal site of the graft

Two-Strand Graft Preparation with ST- The tendon isloaded in a suspensory device with the middle portionof the tendon in the clamp (Fig 1). The 2 freeends of the graft are folded on top of one another, andare stitched together with a nonabsorbable suturetrying to equalize both the ends of the graft. The graftis whipstiched in the distal site of the graft. The first graft is prepared by loading the semitendinosus tendon into a suspensory device with the middle portion secured in the clamp. The two free ends of the graft are folded and stitched together using a nonabsorbable suture to equalize both ends. Finally, the graft is whipstitched at the distal site for added security.

Four-Strand Graft Preparation with ST & GC-Both tendons are loaded in a suspensory devicein a reverse orientation.

A nonabsorbable suture ispassed twice around the 4 free ends of the graft. Thegraft is whipstiched distally with a nonabsorbable suture.

To prepare a four-strand graft using both the semitendinosus (ST) and gracilis (GC) tendons, follow these steps:

Tendon Harvesting: Harvest both tendons using minimally invasive techniques.

Loading in Suspensory Device: Load both tendons into a suspensory device in reverse orientation, securing them to prevent movement.

Stitching the Free Ends: Pass a nonabsorbable suture twice around the four free ends of the tendons to secure them together.

Whipstitching the Graft: Whipstitch the graft distally with a nonabsorbable suture to further secure it.

Trimming and Sizing: Trim the graft to the appropriate length and size for ACL reconstruction

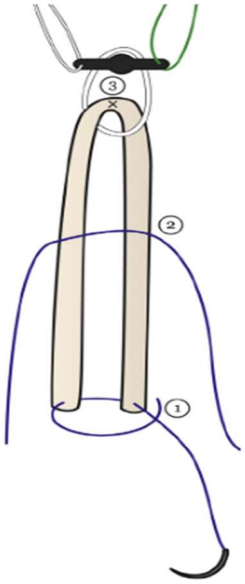


Figure 1: Two-strand and 4-strand graft preparation with 1tendon. (1) Both ends of the tendon are sutured together. In4-strand graft preparation, (2) a nonabsorbable suture is passed in the middle and the tendons are folded. (3) Theneedle is passed through the proximal part, grabbing and tensioning the distal part with the nonabsorbable suture

Postoperative Rehabilitation

All patients followed a standardized postoperative rehabilitation protocol, which included immediate weight-bearing as tolerated with the use of crutches, range of motion exercises starting from the first postoperative day, and gradual progression to strengthening exercises and functional activities. Emphasis was placed on early mobilization and return to normal activities.

Outcome Measures

Functional outcomes were assessed at regular intervals over a period of 20 months, with a mean follow-up of 12 months. The following outcome measures were used:

Lysholm Scoring System: This system evaluates knee function and symptoms, with higher scores indicating better knee function.

IKDC Subjective Scoring: This scoring system assesses subjective knee function and symptoms.

Knee Flexion and Extension Strength Testing: Isokinetic strength testing was used to assess knee flexion and extension strength.

Adherence to Physiotherapy and Yoga: Patients' adherence to the prescribed physiotherapy and yoga regimen was recorded.

Rotational Stability and Anterior Stability: Clinical tests, such as the Lachman test and pivot shift test, were used to assess knee stability.

Return to Day-to-Day Activities: Patients' ability to return to day-to-day activities, including work and recreational activities, was evaluated.

Statistical Analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the patients. Independent t-tests and chi-square tests were used to compare the functional outcomes between the two groups. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all patients, and patient confidentiality was maintained throughout the study.

Limitations

Limitations of the study include its relatively small sample size and short follow-up duration. Additionally, the study did not include a control group, which could have provided further insights into the comparative outcomes of ACL reconstruction using different graft configurations. Further research with a larger sample size and longer follow-up duration is warranted to validate the findings of this study.

3. Results

The research was conducted for ACL Reconstruction on a total of 30 patients from April 2019 to December 2021. The patients were divided into two groups: Group A, consisting of 305 patients, and Group B, also consisting of 30 patients. Group A underwent 2-strand Semitendinosus ACL reconstruction, while Group B underwent 4-strand Semitendinosus and Gracilis ACL reconstruction, with an average follow-up period of 12 months. There were no significant differences observed between the two groups in terms of sex, preoperative period, level of sports activity, and accompanying minor meniscal injuries. Patients who required collateral ligament repair, had bilateral ACL injury, associated bony injury, limb weakness, or polytrauma were excluded from the study. On the other hand, patients with ACL injury, positive clinical tests (Lachman test, Anterior drawers test, Pivot shift test), MRI-diagnosed ACL injury, and old ACL injury were included in the study.

Table-1 Patients Data for 2 strands and 4 strands

	2 Strands	4 Strands
Patient Numbers	30	30
Male	25	18
Female	5	12
Age (Mean + S.D)	31.23±5.77	35.96 ± 5.79
Operation period (< 4 weeks)	8	6
(> 6 weeks)	22	24
Accompanying meniscus injury		
Medial	21	20
Lateral	9	10

The distribution of male and female patients who underwent either a two-strand or a four-strand procedure is presented in the table above. In the case of the two-strand procedure, there were 25 male patients and 5 female patients. This data indicates that a greater number of males opted for the two-strand procedure compared to females. On the other hand, for the four-strand procedure, there was a more equal distribution between males and females, with 18 males and 12 females.

The mean age of patients in the two-strand group is 31.23 years, with a standard deviation of 5.77. In contrast, the average age in the four-strand group is higher, at 35.96 years, with a standard deviation of 5.79. This suggests that patients who undergo the four-strand procedure tend to be older. In terms of the operation period, 8 patients in the two-strand group had their surgery within 4 weeks, while 6 patients in the four-strand group underwent the procedure within the same timeframe. A significant number of patients in both groups had their operation after more than 6 weeks, with 22 patients in the two-strand group and 24 patients in the four-strand group falling into this category.

Furthermore, both medial and lateral forms of concomitant meniscus injuries have been found to occur. Nine individuals in the two-strand group sustained lateral meniscus tears, while 21 patients experienced medial meniscus lesions. In the same way, 10 patients in the four-strand group had lateral meniscus tears and 20 patients had medial meniscus injuries. These numbers show that the distribution of meniscus injuries in the two groups is quite comparable.

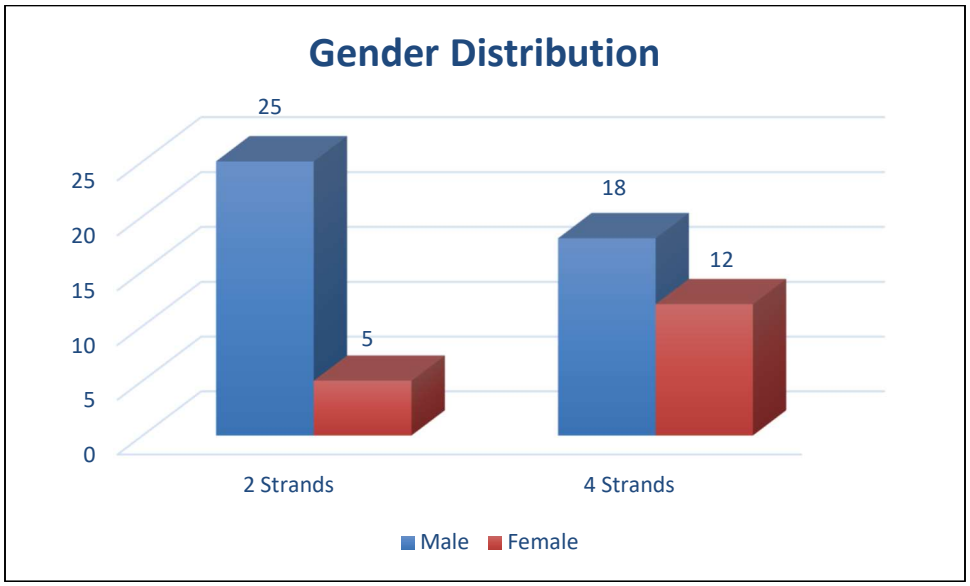


Figure 2: Gender Distribution

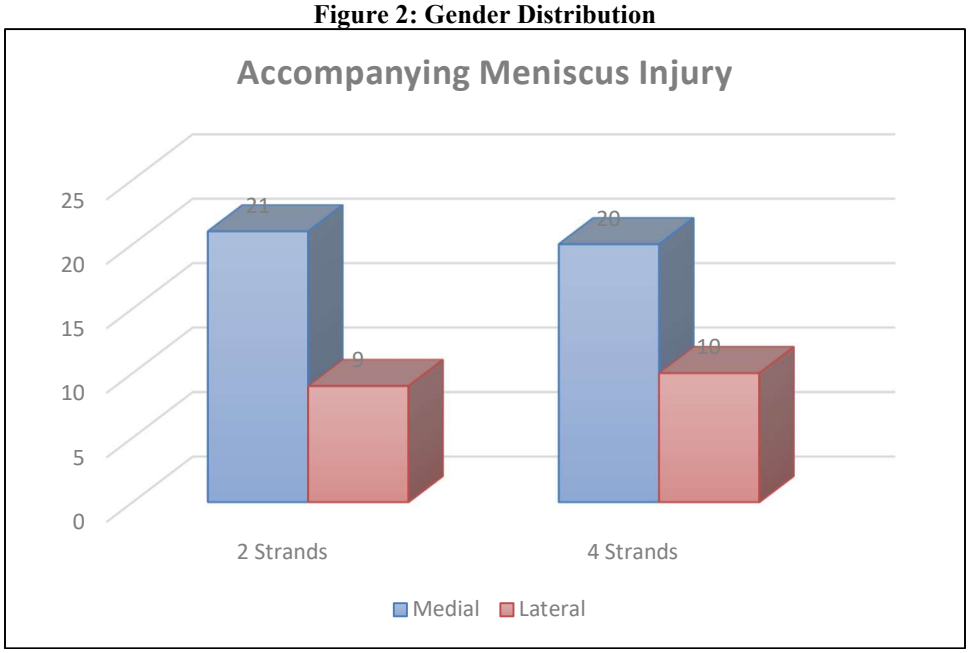


Figure 3: Accompanying Meniscus Injury

Table 2: Patient Characteristics in Treatment

Mode of Injury		
	Patients	**Percentage**
Sports	11	18.3
Fall	28	46.7
Road Traffic Accident	21	35.0
Total	60	100.0
Duration after Injury		
	Patients	**Percentage**

< 6 weeks	10	16.7
6 weeks – 3 months	11	18.3
3 – 6 months	13	21.7
6 – 12 months	12	20.0
> 12 months	14	23.3
Total	60	100.0

In terms of proportion of total injuries, the table 2 displays the distribution of injury mechanisms among the patients. Falls account for 46.7% of cases, making them the most common mode of injury. Road traffic accidents account for 35% of injuries and are the second most common cause. With 18.3% of all injuries being related to sports, these are the least prevalent types of injuries.

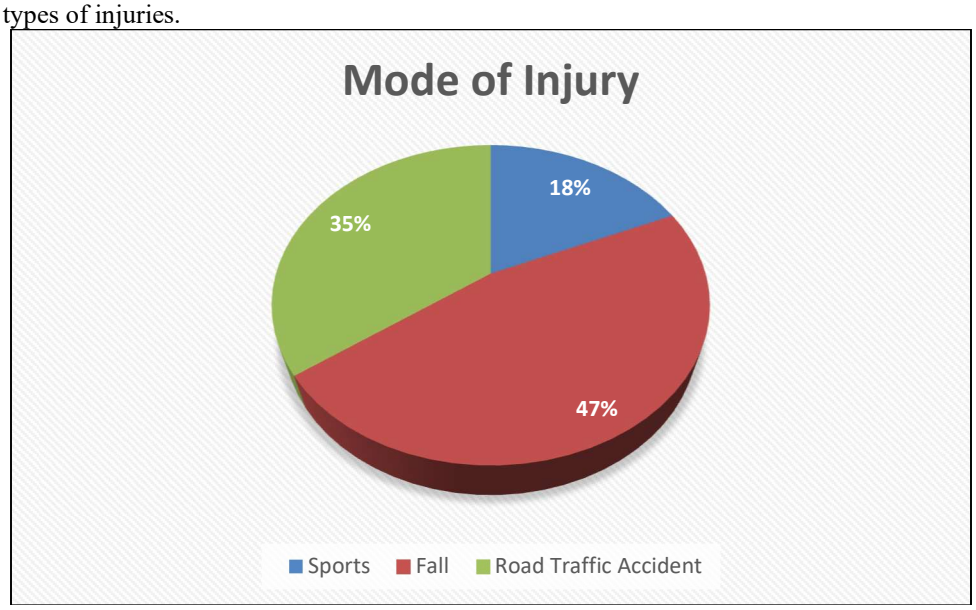


Figure 4: Mode of Injury

From these percentages for duration after injury, it can be observed that the largest group of patients (23.3%) sought treatment more than 12 months after their injury. The next most common duration is 3 to 6 months, accounting for 21.7% of the patients. The percentages for the 6 weeks to 3 months and 6 to 12 months categories are relatively close, at 18.3% and 20%, respectively. The smallest proportion of patients, 16.7%, received treatment within the first 6 weeks post-injury.

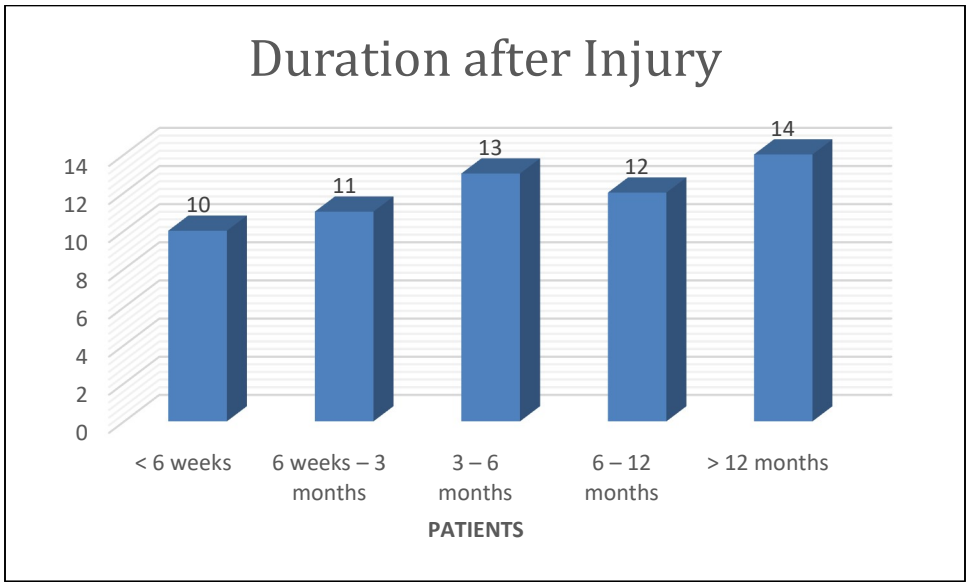


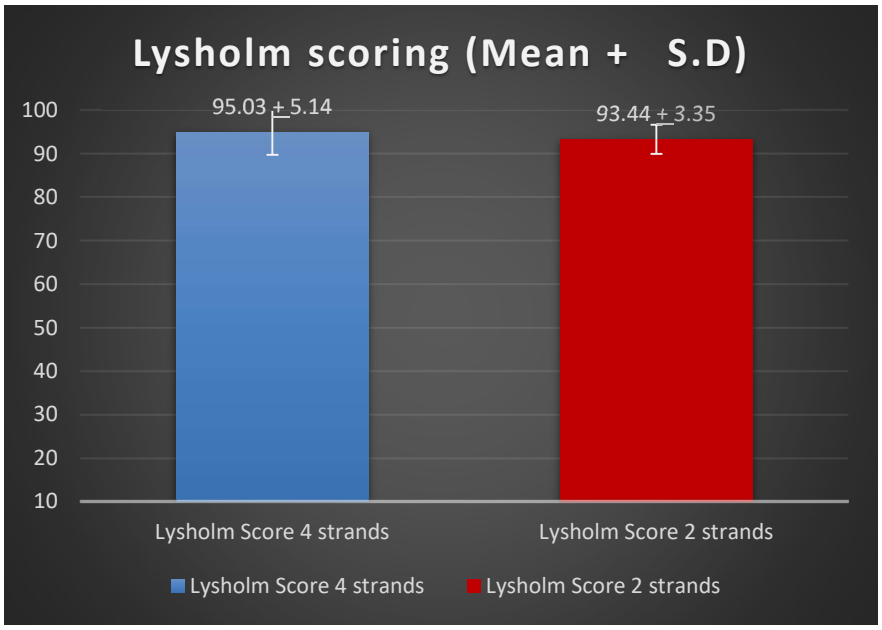
Figure 5: Duration after Injury

When comparing the means of two related groups, a paired sample t-test—also called a dependent sample t-test—is a statistical technique that is employed. This test is frequently used when individuals are measured both before and after a treatment, or when subjects are meaningfully matched in pairs. t-test is used to compare Lysholm Score and IKDC Score obtained through 2 strands and Lysholm Score and IKDC Score obtained through 4 strands.

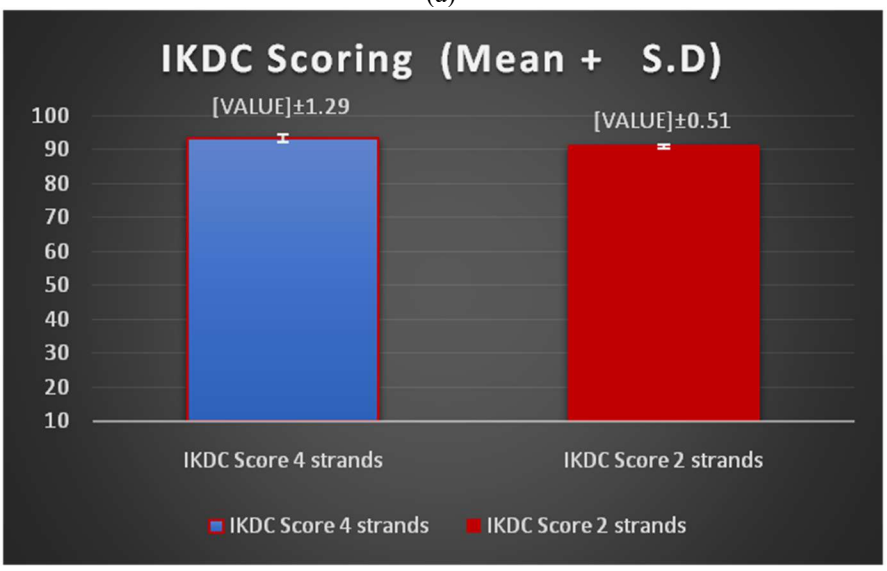
Table 3 Paired Sample Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Lysholm Score 2 strands	93.44	30	3.35	0.61
	Lysholm Score 4 strands	95.03	30	5.14	0.94
Pair 2	IKDC Score 2 strands	90.92	30	2.77	0.51
	IKDC Score 4 strands	93.35	30	7.09	1.29

Due to the means of Lysholm Score for 2 strands and the direction of the t-value, we can conclude that there was a statistically significant improvement in patients following the results of 2 strands and 4 strands from 93.44 ± 3.35 to 95.03 ± 5.14 ($p < 0.0005$); an improvement of 1.59 ± 1.79. Similarly comparing the means for IKDC Score for 2 strandsand the direction of the t-value, we can conclude that there was a statistically significant improvement in patients following the results of 2 strands and 4 strands from 90.92 ± 2.77 to 93.35 ± 7.09 ($p < 0.05$); an improvement of 2.43 ± 4.32.



(a)



(b)

Figure 1 Functional outcome of (a) Lysholm score & (b) IKDC Score post-surgery followup

The mean Lysholm scores were found to be higher in the 4-strand condition (95.03) compared to the 2-strand condition (93.44). Moreover, the standard deviation was slightly larger in the 4-strand condition (5.14) than in the 2-strand condition (3.35), suggesting greater variability in scores for the former. Additionally, the standard error of the mean was higher in the 4-strand condition (0.94) than in the 4-strand condition (0.61), indicating differences in the precision of the sample mean.

The mean IKDC scores for the 4-strand condition are higher (93.35) in comparison to the 2-strand condition (90.92). Notably, the standard deviation for the 4-strand condition (7.09) is larger than that of the 2-strand condition (2.77), indicating a greater variability in the 2-strand scores. Additionally, the standard error of the mean is higher for the 4-strand condition (1.29) when compared to the 2-strand condition (0.51).Lysholm and IKDC scores are often higher for the 4-strand condition than for the 2-strand condition, according to the data. Higher performance ratings or better outcomes are shown by the larger means in the 4-strand condition. But there appears to be more variation in these results given the higher standard deviations in the 4-strand circumstances.

Table 4 Paired Sample test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Lysholm Score 2 strands - Lysholm Score 4 strands	-1.588	3.441	0.628	-2.873	-0.303	-2.528	29	0.017
Pair 2	IKDC Score 2 strands - IKDC Score 4 strands	-2.426	5.649	1.031	-4.535	-0.317	-2.352	29	0.026

A comparative analysis was conducted using a paired sample t-test to assess the differences in Lysholm scores and IKDC scores between patients who underwent two-strand and four-strand procedures. The results revealed a significant disparity in Lysholm scores between the two groups, with a t-value of -2.528 (df = 29, p = 0.017). The mean difference was calculated to be -1.588, accompanied by a standard deviation of 3.441 and a standard error of the mean of 0.628. The 95% confidence interval for the difference ranged from -2.873 to -0.303. These findings suggest that, on average, the Lysholm score for patients who underwent the two-strand procedure was significantly lower than that for those who underwent the four-strand procedure.

In a similar vein, the IKDC scores exhibited a notable distinction between the two-strand and four-strand procedures; t(29) = -2.352, p = 0.026. The mean difference was -2.426, with a standard deviation of 5.649 and a standard error of the mean of 1.031. The 95% confidence interval for the difference was between -4.535 and -0.317. This data implies that, on average, the IKDC score for the two-strand procedure was significantly lower than that for the four-strand procedure. To summarize, both the Lysholm and IKDC scores support the notion that the four-strand procedure yields superior results compared to the two-strand procedure, as evidenced by the significant score variances.

4. Discussion

The study assessed various outcome measures, including knee strength, range of motion, thigh girth, and patient-reported outcome scores. Considering the study conducted on evaluation on the overall efficacy with the consistent physiotherapy and rehabilitation on the functional outcomes of ACL reconstruction using these graft configurations [19]. In addition to graft choice, the study will also evaluate the impact of consistent physiotherapy and rehabilitation on the functional outcomes of ACL reconstruction. Previous studies have highlighted the importance of postoperative rehabilitation in achieving optimal outcomes following ACL reconstruction [20]. Consistent physiotherapy and rehabilitation can help improve knee strength, range of motion, and functional outcomes [21].The selection of the optimal graft configuration for ACL reconstruction remains a topic of debate among orthopedic surgeons [22]. While both two-strand and four-strand hamstring autografts have shown promising results, there is a lack of consensus regarding which graft configuration provides superior functional outcomes. This study aims to address this gap in the literature by comparing the functional outcomes of ACL reconstruction using these two graft configurations.

The primary aim of ACL reconstruction is to regain the full range of movements and get full stability as early as possible. Many authors proposed many types of surgical techniques [8]. The choice of fixation of ACL by Endobutton in Femur and interference screw in tibia is accepted by many surgeons worldwide. This will help in smoother rehabilitation of the patients. The current concepts of ACL reconstruction is aggressive early rehabilitation with early active mobilisation and weight bearing. [9]. All the patients in our study underwent arthroscopic ACL recontruction with two -strands Semitendinosus and four- strands semitendinosus and gracilis tendon autograft from ipsilateral limb and fixation by Endobutton on femur side and bio absorbable screw on tibial side. The mean age of patients in our study was 22±4. In our study, males were more commonly affected than females. Right side knee was more injured than left. With regard to mode of injury, Chaudhary D et al (2005) noted that injury caused by sporting activities accounted for 66.7% whereas road traffic accidents and domestic injuries accounted for 30.8% and 2.5% respectively [10]. Patond KR et al (1992) revealed that

sports activities were the predominant cause of ACL injury [11]. In our study, most sportspersons from sports academy and less numbers from RTA affected patients were included. The most common sports injuries were from football, basketball, hockey and volleyball. We treated all the acute injuries with knee brace for 4 weeks and ice fomentation for first week in order to settle the inflammatory reactions. In our study, the size of the graft used in 2 strands semitendinosus technique is 7mm mostly (53.3%) and the majority of (53.3%) 8mm size in 4 strands technique. Manual laxity test such as Lachman test, Pivot shift test and Anterior Drawer test were carried out periodically in all the patients at the end of 1st, 3rd, 6th and 12th month. At 12-month average follow-up, two patients (6.7%) had positive pivot shift in both techniques (Grade-1). Remaining 28 patients (93.3%) had negative pivot shift.

In terms of the functional outcome, our study showed that all the patients had undergone fixed postoperative protocol since all were young patients. Our study's findings indicate that patients who underwent ACL reconstruction with the 4-strand hamstring autograft technique achieved better functional outcomes compared to those with the 2-strand technique, as evidenced by higher Lysholm and IKDC scores. Specifically, the mean Lysholm score for the 4-strand condition was 95.03, higher than the 93.44 observed in the 2-strand condition. Similarly, the mean IKDC score was 93.35 for the 4-strand condition, compared to 90.92 for the 2-strand condition. These results suggest that the 4-strand technique provides a slightly better functional performance post-surgery.These findings are consistent with several other studies in the field. Chee et al. (2017) reported that the 4-strand hamstring autograft technique provided superior stability and functional outcomes in their followup findings [23].

Similarly, a meta-analysis by Goldblatt et al. (2005) found that the tensile properties concerning with the multiple-stranded HT grafts like 4 strands serving as an additive only when all 4 strands are equally tensioned. Studies suggestive on the fact that in case of an unequally tensioned 4-strand grafts are equivalent in strength to a 2-strand graft, and thus, emphasismust be placed on surgical technique [24].

Our findings also align with those of He et al. (2020), who observed that the 4-strand technique resulted in better knee stability and patient satisfaction at long-term follow-ups. They suggested that the biomechanical advantages of the 4-strand graft, such as its higher tensile strength and resistance to elongation, contribute to these improved outcomes [25].However, it is important to note that while the 4-strand technique demonstrates superior outcomes, it also shows greater variability in results. This is evidenced by the higher standard deviations in the 4-strand condition for both Lysholm (5.14) and IKDC (7.09) scores, compared to the 2-strand condition (3.35 and 2.77, respectively). The larger standard deviations suggest that there is more variation in the outcomes for patients receiving the 4-strand graft. Additionally, the standard error of the mean was higher in the 4-strand condition for both Lysholm (0.94 vs. 0.61) and IKDC (1.29 vs. 0.51) scores, indicating differences in the precision of the sample mean.

This increased variability could be due to several factors, including differences in surgical technique, patient characteristics, or rehabilitation protocols. For instance, Joreitz et al. (2016) suggested that variations in individual patient anatomy and activity levels might influence the outcomes of ACL reconstruction. Furthermore, the learning curve associated with the 4-strand technique might contribute to the observed variability, as surgeons become more proficient with the method over time.

5. Conclusion

In conclusion, our study supports the superiority of the 4-strand hamstring autograft technique for ACL reconstruction in terms of functional outcomes, as indicated by higher Lysholm and IKDC scores. However, the greater variability in these results suggests the need for further research to identify and mitigate factors contributing to this variability. Future studies could focus on standardizing surgical techniques and post-operative rehabilitation protocols to minimize outcome disparities and optimize patient recovery.

The functional outcomes were rated as Excellent to Good for patients who received four-strand semitendinosus and gracilis tendon grafts compared to those who received two-strand semitendinosus grafts.Additionally, most patients were able to return to their pre-injury activity levels at the 12-month follow-up. To protect the ACL graft, patients were advised against sitting cross-legged for up to 12 months post-surgery.Our study aims to bridge this gap by providing valuable information to guide clinical practice, enabling surgeons to make informed decisions regarding graft selection. This, in turn, can lead to a more robust recovery in a shorter time frame, facilitating a return to normal activities for individuals.

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