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ORIGINAL ARTICLE

Comparing Clinical Outcomes of Five-Strand Hamstring Tendon Autograft and Quadrupled Hamstring Tendon Autograft for Single Bundle Anterior Cruciate Ligament Reconstruction in Filipinos: An Ambi-directional Cohort Study

Albert Ian J. Villegas, MD, Emmanuel Roy D. Mata, RN, MD, FPOA, Jose Antonio G. San Juan, MD, FPOA, John Rey T. Go, MD, FPOA, Vick Roland L. Ladica, MD, FPOA

Department of Orthopedics, Chong Hua Hospital, Cebu City, Philippines

ABSTRACT

Background. Anterior cruciate ligament (ACL) tears are common, especially in athletes, and are often treated with hamstring tendon autografts using a single-bundle technique. Graft diameter is crucial, with evidence showing that larger grafts reduce failure risk. Asian populations typically have smaller graft diameters. This study compares the clinical outcomes of the five-strand versus the quadrupled technique in a Filipino Asian population to assess potential benefits in graft thickness and knee stability.

Objective. To compare the functional outcomes, graft sizes, failure rates, and time to return to sports between five-strand and quadrupled hamstring tendon autografts in ACL reconstruction.

Methodology. This ambi-directional cohort study involved Asian Filipino patients aged 18–50 with unilateral ACL tears who underwent single-bundle ACL reconstruction with either quadrupled or five-strand hamstring autografts between January 2022 and August 2023. Data on graft dimensions, IKDC scores, and time to return to sports were collected pre- and postoperatively. The analysis included descriptive statistics, Fisher's exact test, t-tests, and ANOVA, with significance at $p < 0.05$.

Results. The study included 18 patients, showing no significant differences in demographic characteristics such as age (24.78 vs. 27.67 years, $p = 0.202$), height (1.71 vs. 1.64 meters, $p = 0.146$), weight (84.43 vs. 74.98 kg, $p = 0.252$) body mass index (28.95 vs. 27.98 kg/m², $p = 0.714$), or average return to sports (10.63 vs. 11.83 months, $p = 0.642$). There was no significant difference in thicknesses ($p = 0.089$) and lengths ($p = 0.885$) of the graft. IKDC scores showed no significant differences between the two groups in pre- or postoperative outcomes at six months and one year. Complications were minimal, with no significant difference found.

Conclusion. Both the five-strand and quadrupled techniques demonstrated similar demographics, graft dimensions, and clinical outcomes, indicating comparable functional results and safety profiles.

Keywords. anterior cruciate ligament, reconstruction, hamstring tendon autograft, five-strand tendon autograft, single-bundle technique, outcomes

INTRODUCTION

The quadrupled hamstring tendon graft has become the graft of choice in anterior cruciate ligament (ACL) reconstruction because of its biomechanical properties that mimic or even outperform the native ACL, the ease of harvesting, good clinical outcomes, and minimal donor site morbidity.[1-3] The quadrupled configuration is obtained by folding the gracilis and semitendinosus tendons once.[4] Multiple and thicker strands correlate with higher graft strength and lower risk of graft revision.[5,6] The estimated risk of graft failure is at 1.8% to 10.4%,[7,8] which is decreased by 0.82 to 0.86 times with every 0.5 mm increase in graft diameter between 7.0 and 10.0 mm.[9,10] The Asian hamstring autografts are usually smaller than their Caucasian counterparts—around 7 mm for females and 8 mm for males.[11] Tang et al. found that a target graft diameter

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Corresponding author: Albert Ian J. Villegas, MD
Department of Orthopedics
Chong Hua Hospital, Fuente Osmeña,
Don Mariano Cui St., Cebu City, 6000 Cebu, Philippines
Tel. No.: (032) 233-8000
E-mail: albertijvillegas@gmail.com
ORCiD: https://orcid.org/0009-0007-5473-7808

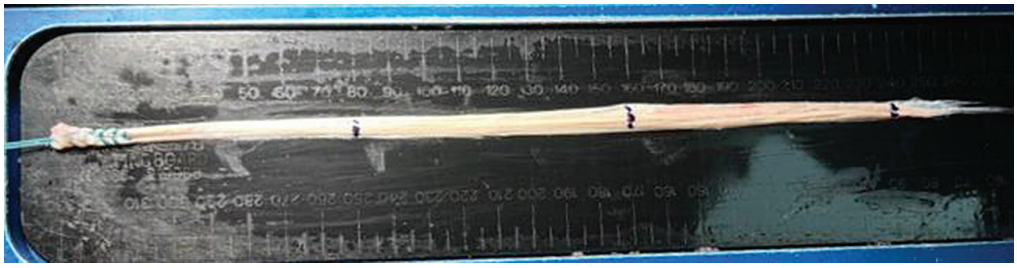

Figure 1. Semitendinosus tendon marked into three parts for a five-strand hamstring auto graft.

of 8 mm or more decreases the risk of graft failure and that race may help predict graft failure in ACL reconstruction.[12]

In a Multicenter Orthopaedic Outcomes Network (MOON) cohort study of more than 250 patients, patient-reported outcomes were better with larger-diameter hamstring grafts. Specifically, 5.2-, 3.3-, and 2.0-point increases in KOOS Sports, Pain, and Activities of Daily Living scores, respectively, were observed for every 1 mm increase in graft diameter, with a 3.4-point increase in the subjective International Knee Documentation Committee (IKDC) score.[13] Generally, a thicker graft is a goal for every ACL reconstruction case.

Despite the promising outcomes of the hamstring tendon autograft, an important drawback is its variability in diameter.[14] Several techniques have been described to increase the hamstring autograft diameter when presented with a less than 8.0 mm diameter graft. In the five-strand hamstring tendon autograft, the longer semitendinosus tendon is folded into three equal parts (Figure 1) while the gracilis tendon is folded in half once. This technique has been known to increase the graft diameter by an average of 1–2 mm according to Lavery et al.[15]

Few studies discuss the clinical outcomes of the five-strand hamstring tendon autograft. Calvo et al. found that a five-strand graft was clinically comparable with a four-strand graft in terms of re-rupture rates and clinical outcomes (both grafts being >8 mm). Krishna et al.'s cohort study also concludes that when faced with an undersized graft, the five-strand graft technique is useful in increasing the graft diameter providing a good and valid option comparable to the standard quadrupled technique.[16]

The goal is to restore the stability of the knee, expediting return to sports while minimizing the risk of retear, translating to a high functional clinical outcome. The study aimed to compare the clinical outcomes of the five-stranded hamstring autograft in a Filipino population versus the quadrupled hamstring tendon autograft for single-bundle reconstruction for patients with anterior cruciate ligament tears.

METHODOLOGY

Study design

This was an ambidirectional cohort study.

Study setting

This study was done at Chong Hua Hospital, Fuente Osmeña, Don Mariano Cui St., Cebu City, Philippines.

Study population

Inclusion criteria

This study included Filipino patients ages 18–50 years old with unilateral complete anterior cruciate ligament tears: who underwent a primary single-bundle reconstruction using hamstring tendon autografts; from January 2022 to August 2023; where a meniscectomy or meniscal repair may or may not have been done; performed in Chong Hua Hospital; where either a quadrupled hamstring autograft or a five-strand hamstring autograft was harvested; where a cortical button was used for the femoral end and a bioabsorbable interference screw for the tibial end of the ACL graft; who consented to be included in the study; and completed at least one year of follow-up.

Exclusion criteria

This study did not include: bilateral ACL tear patients; patients with other ligamentous injuries such as PCL or collateral ligament injuries; those with previous surgeries on the operated knee; cases of ACL revision; and patients wherein the number of strands were not indicated or did not belong to a quadrupled or a five-strand autograft in the records.

Sample size determination

Total sampling of patients meeting the inclusion and exclusion criteria.

Research tool

The research tool that was used was the International Knee Documentation Committee Subjective Knee Form (IKDC).

Data collection

The study was approved by the Chong Hua Hospital Institutional Review Board. Patients who fit the inclusion and exclusion criteria were appraised and gave their consent. Patients underwent anterior cruciate ligament reconstruction using hamstring grafts. If the harvested tendons were long enough to be folded to create a five-strand graft, patients were

assigned to the intervention group, while harvested tendons that were too short for a five-strand graft were assigned to the control group.

The surgeon harvested the hamstring autografts with care to maximize the tendon length. The tendons were transferred to the graft preparation table and stripped of excess muscles on the proximal end. For the five-strand technique, the surgeons must have harvested a total of 240 mm for the semitendinosus and 160 mm for the gracilis. Any excess length was cut off. The gracilis was folded once while the semitendinosus was folded into three equal parts, making it the same length as the folded gracilis. The target length was 80–90 mm (20 mm femoral tunnel graft, 30 mm intra-articular graft, and 30–40mm tibial tunnel graft). The tendons were whipstitched together with the cortical button applied on one end.[11] The quadrupled autografts were prepared similarly, with the difference being that both the semitendinosus and the gracilis were each folded over once.

Patients who did not concomitantly undergo a meniscal repair were allowed immediate weight-bearing and range of motion. For patients with meniscal repairs, weight-bearing was delayed up to two weeks, and range of motion was delayed for four weeks. The rehabilitation regimen after this period was the same for all patients thereafter.

Demographic data, pre- and postoperative IKDC scores, harvested graft length and diameter, and intraoperative and postoperative adverse events were recorded. Six- and twelve-month follow-up outcomes were collected via interview, including IKDC scores and time required to return to sports.

Data management and analysis

In this study, continuous variables were summarized using means and standard deviations, while nominal variables were summarized using frequencies and percentages. Fisher's exact test was used to compare nominal variables, and the t-test was used for continuous variables. One-way repeated measures ANOVA was used to compare matched or repeated measures. When ANOVA results were significant, a conditional post hoc analysis was performed. The level of statistical significance was set at $p < 0.05$.

RESULTS

A total of 18 patients were included in this study, nine cases each for the five-strand and the quadrupled groups. Demographic data revealed that the five-strand and quadrupled groups were well-matched across several characteristics, with no statistically significant differences observed for age, sex, height, weight, BMI, etiology of injury, and time to operation (Table 1). While more patients in the five-strand group had left-sided injuries (55.56%), compared to the quadrupled group (22.22%), this difference was not statistically significant ($p = 0.335$).

The mean graft diameter in the five-strand group was 8.17 mm ($SD = 0.87$), and 7.56 mm ($SD = 0.53$) in the quadrupled group ($p = 0.089$), with no statistically significant difference. The five-strand group's mean graft length was 85.00 mm ($SD = 10.00$), while the quadrupled group's was 85.56 mm ($SD = 5.27$), with no significant difference ($p = 0.885$). The five-strand group displayed a wider range of sizes, with the most common dimensions (diameter x length) being 8 x 80 mm (33.33%), followed by 8 x 100 mm (22.22%). Other sizes such as 7 x 70 mm, 9 x 80 mm, 7.5 x 85 mm, and 10 x 90 mm were observed less frequently (each at 11.11%). In contrast, the quadrupled group showed a concentration in specific sizes, with 8 x 90 mm (33.33%) being the most common, while 7 x 80 mm and 7 x 90 mm were observed in 22.22%. There was no significant difference in graft diameter between the two groups ($p = 0.066$) (Table 2).

Among patients with sports-related injuries, there was no significant difference in the average time to return to sports ($p = 0.642$) (Table 3).

There were no significant differences in preoperative measures for IKDC Symptoms, Sports, Function, and Total scores (Table 4, $p > 0.05$). However, significant changes were observed

Table 1. Patient demographics

	Five-strand Group (n = 9)	Quadrupled Group (n = 9)	*p* Value
Age, (years)	24.78 (3.15)	27.67 (5.70)	0.202
Gender, n (%)			
Male	7 (77.78)	6 (66.67)	1.000
Female	2 (22.22)	3 (33.33)	
Height, (cm)	1.71 (0.08)	1.64 (0.10)	0.146
Weight, (kg)	84.43 (22.31)	74.98 (8.39)	0.252
Body Mass Index in kg/m²	28.95 (7.23)	27.98 (2.59)	0.714
Time to Operation (months)	20.33 (28.40)	29.22 (39.33)	0.590
Laterality, n (%)			
Left	5 (55.56)	2 (22.22)	0.335
Right	4 (44.44)	7 (77.78)	
Type of Injury, n (%)			
Non-sports	1 (11.11)	3 (33.33)	0.577
Sports	8 (88.89)	6 (66.67)	

Note: * Significant at 0.05; Values are presented in mean (standard deviation) unless otherwise stated.

within each group over time. In the five-strand group, IKDC scores for symptoms, sports, and total IKDC significantly increased at six months post-operation, indicating an improvement in knee function and a reduction in symptoms shortly after the operation. Despite this initial increase, scores stabilize after one year. Conversely, in the quadrupled group, there was a significant increase in IKDC sports, function, and total scores at six months, reflecting improved ability to participate in sports while also indicating a general improvement in knee function and overall health. A significant increase in symptoms score was observed at one year, with the total score continuing to increase significantly, indicating ongoing improvement. These findings highlight distinct patterns of change, with each group showing different trajectories in knee health and functionality following their respective interventions.

There were no cases of tunnel blowout, graft failure, or stiffness in either group (Table 5). One patient had instability (11.11%) in the five-strand group, while there were none in the quadrupled group (p = 1.00). For miscellaneous complications, the five-strand group had one case of meniscus injury at 10 months postoperatively and another case of partial tear of the ACL at 15 months postoperatively; no

Table 2. Graft dimensions and measurements

	Five-strand Group (n = 9)	Quadrupled Group (n = 9)	*p* Value
Average graft thickness	8.17 (0.87)	7.56 (0.53)	0.089
Average graft length	85.00 (10.00)	85.56 (5.27)	0.885
Dimensions of the graft (mm)			
7 x 70	1 (11.11)	0 (0.00)	0.066
7 x 80	0 (0.00)	2 (22.22)	
7 x 90	0 (0.00)	2 (22.22)	
8 x 80	3 (33.33)	2 (22.22)	
8 x 90	0 (0.00)	3 (33.33)	
8 x 100	2 (22.22)	0 (0.00)	
9 x 80	1 (11.11)	0 (0.00)	
10 x 90	1 (11.11)	0 (0.00)	

Note: * Significant at 0.05; values are presented in frequency (percentage).

Table 3. Time to return to sports (among patients with sports-related injuries, n = 14)

	Five-strand Group (n = 8)	Quadrupled Group (n = 6)	*p* Value
Return to sports (months)	10.63 (2.88)	11.83 (6.43)	0.642

Note: * Significant at 0.05; Values are presented in mean (standard deviation) unless otherwise stated.

Table 4. Comparison of outcomes

	Five-strand group (n = 9)	Quadrupled group (n = 9)	Between groups comparison, *p* value
Pre-operative scores			
IKDC symptoms	23.44 (7.54) [A]	26.67 (4.42) [A]	0.285
IKDC sports	24.78 (9.43) [A]	26.33 (8.37) [A]	0.716
IKDC function	8.11 (1.54)	7.33 (2.18) [A]	0.395
Total	64.75 (19.75) [A]	69.35 (14.82) [A]	0.584
Post-operative scores 6 months			
IKDC symptoms	30.56 (6.39) [B]	29.22 (3.90) [A]	0.600
IKDC sports	36.56 (4.42) [B]	35.67 (5.77) [B]	0.718
IKDC function	8.89 (1.17)	8.89 (1.17) [B]	1.000
Total	87.36 (11.68) [B]	84.80 (9.97) [B]	0.625
Post-operative scores 1 year			
IKDC symptoms	33.78 (4.68) [B]	35.33 (2.18) [B]	0.380
IKDC sports	39.00 (1.66) [B]	39.44 (0.73) [B]	0.472
IKDC function	9.67 (0.71)	9.44 (1.01) [B]	0.597
Total	94.76 (7.80) [B]	96.81 (2.97) [C]	0.473
Within group comparison	***p* value**	***p* value**	
IKDC symptoms	<0.001 *	<0.001 *	
IKDC sports	<0.001 *	<0.001 *	
IKDC function	0.015 *	<0.001 *	
Total	<0.001 *	<0.001 *	

Note: * Significant at 0.05; Values are presented in mean (standard deviation); different superscripts indicate significant differences in scores with the group; IKDC stands for International Knee Documentation Committee Subjective Knee Form.

Table 5. Complications

	Five-strand Group (n = 9)	Quadrupled Group (n = 9)	*p* Value
Tunnel blowout	0 (0.00)	0 (0.00)	1.000
Graft failure	0 (0.00)	0 (0.00)	1.000
Stiffness	0 (0.00)	0 (0.00)	1.000
Instability	1 (11.11)	0 (0.00)	1.000
Others	2 (22.22)	0 (0.00)	0.471

Note: * Significant at 0.05; values are presented in frequency (percentage).

miscellaneous complications were observed in the quadrupled group ($p = 0.471$). Overall, the rates of complications were low and comparable between the two groups.

DISCUSSION

This study compared the clinical outcomes and demographic characteristics of two treatment groups: the five-strand and quadrupled hamstring tendon autograft groups. The primary focus was on graft thickness, clinical outcomes, and complication rates.

Patient demographics and baseline characteristics

The groups were well-matched in terms of age, gender, height, weight, BMI, time to operation, laterality, and injury type, making these variables less likely to confound the outcomes.

Graft dimensions

Graft dimensions were similar between the five-strand and quadrupled groups. The five-strand group had a mean thickness of 8.17 mm (SD = 0.87) and length of 85.00 mm (SD = 10.00), while the quadrupled group had a mean thickness of 7.56 mm (SD = 0.53) and length of 85.56 mm (SD = 5.27), falling within the 7–8 mm range for Asian populations.[1] Differences in thickness ($p = 0.089$) and length ($p = 0.885$) between the two groups were not statistically significant. While the variability in graft sizes was not substantial ($p = 0.066$), the five-strand group demonstrated a wider range of sizes while the quadrupled group showed concentration in specific sizes. We theorize that wide variability in graft thickness could influence the mechanical properties of the graft and potentially affect patient outcomes. However, since we found no statistically significant variability, it is unlikely to be a major confounder in this study.

Clinical outcomes

The IKDC scores provide insights into knee function and recovery over time. Both groups showed significant improvements in symptoms, sports participation, and overall knee function at six months postoperative. However, the trajectory of recovery diverged in one year. The five-strand group saw stabilization in scores, suggesting a plateau in recovery after the initial improvement. In contrast, the quadrupled group continued to show significant gains, particularly in symptoms and overall health.

These findings highlight that while both graft types led to substantial improvements, the quadrupled group may have experienced continued benefits beyond the six-month mark. This could suggest that the quadrupled graft offered a more sustained improvement in knee function, although the clinical significance of these differences would need further exploration in larger studies. Overall, for both groups, we noted almost equivalent outcomes.

Complications

Complication rates were low and comparable between the groups, with no significant differences in tunnel blowout, graft failure, stiffness, or other complications. There was one case of instability, one case of meniscus injury at 10 months, and a partial ACL tear at 15 months in the five-strand group, but no statistically significant difference was found when comparing these incidences with the quadrupled group. The low rate of complications suggests that both graft types are generally safe and well-tolerated. This supports the use of either technique in clinical practice, although individual patient factors and preferences should guide the choice of graft. We note that our follow-up period was short, which might not capture all possible complications.

The postoperative protocol for patients with isolated ACL reconstruction, or with meniscectomy followed standard practices of immediate weight-bearing and range of motion.[17] For those with ACL reconstruction and meniscal repair, the rehabilitation started with a protocol for isolated meniscal repairs. Adams recommends for ACL reconstruction with meniscal repair a period of no weight-bearing for four weeks, followed by a gradual reintroduction of weight-bearing over the next four weeks, with standard ACL reconstruction protocol resuming after eight weeks.[17] Accelerated protocols, including the 2018 Knee Pain and Mobility Impairments guidelines, recommend early progressive motion and weight-bearing, achieving full weight-bearing by six to eight weeks.[18] Our study employed an accelerated rehabilitation protocol while ensuring clinical milestones were met. After four weeks, the same protocol was followed for ACL reconstruction with meniscectomy, without meniscectomy, and with meniscal repair.

CONCLUSION

Overall, this study finds that the five-strand and quadrupled groups are comparable in demographic and clinical characteristics, with no significant differences in baseline measures or complications. Both treatments resulted in significant improvements in knee function at six months, though the quadrupled group demonstrated a trend toward continued recovery beyond up to one year. Still, this difference is not statistically significant. While there may have been differences in graft thickness and recovery trajectories, they were not likely to substantially alter the overall safety and effectiveness profiles of the two treatments. Future research with larger sample sizes and longer follow-ups could provide

more definitive insights into the long-term benefits and optimal use of each graft type.

RECOMMENDATIONS

The researchers would like to recommend the following for future studies: (1) a larger population size and/or a longer study period; (2) incorporating correlation between gender and graft dimensions; (3) a population focused on anterior cruciate ligament reconstruction only; and (4) more frequent intervals for outcome measures.

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STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

AUTHORS DISCLOSURE

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