All-Inside Anterior Cruciate Ligament Reconstruction Using Quadrupled Semitendinosus: Comparable 2-Year Outcomes in Male and Female Patients

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Purpose: To determine 2-year functional outcomes using an all-inside quadrupled semitendinosus anterior cruciate ligament (ACL) reconstruction technique in male and female patients. **Methods:** A total of 100 patients who underwent quadrupled semitendinosus all-inside hamstring ACL reconstruction by a single surgeon were enrolled. Patient-reported outcome scores collected preoperatively and postoperatively included visual analog scale, Veterans Rand 12-Item Health Survey (VR-12; Physical and Mental), Marx Activity Scale, Knee Injury and Osteoarthritis Outcome Scores (KOOS), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). **Results:** A total of 100 ACL reconstructions comprising 62 female, and 38 male patients were included in this study. Mean graft diameter was 9.4 mm in female and 9.8 mm in male patients (range, 9-11). Outcome scores demonstrated improvement from preoperative to 2-year postoperative respectively: visual analog scale pain 3.18, 1.07, VR-12 physical 36.35, 52.64, VR-12 mental 53.96, 54.65, KOOS pain 59.17, 89.03, KOOS symptoms 52.64, 80.79, KOOS Activities of Daily Living 69.38, 95.4, KOOS Sport 28.97, 81.25, KOOS Quality of Life 27.54, 71.56, WOMAC Pain 71.56, 92.65, WOMAC Stiffness 60.55, 84.13, and WOMAC Function 69.38, 95.4. Marx activity score decreased from baseline (10.98) to 2 years' postoperatively (8.75). At 2 years, patient expectations were met or exceeded with regards to pain (94%), motion and strength (91%), normal function of daily living (95%), and return to sport (79%). **Conclusions:** Anatomic all-inside quadrupled semitendinosus ACL reconstruction improves functional outcomes similarly to previous studies between baseline and clinical follow-up at 1-year and 2-years postoperatively and is comparable in both male and female patients. **Level of Evidence:** Level III, retrospective comparative study.

Anterior cruciate ligament (ACL) injury is common, with an incidence of approximately 100-200,000 cases per year in the United States and a reported 8 times greater incidence in female athletes.[1-3] The literature is vast with studies on improving ACL outcomes, yet controversy still exists on femoral tunnel drilling technique, graft choice, fixation, postoperative rehabilitation, return to sport, and postoperative bracing.

Anterior cruciate ligament reconstruction (ACLR) is performed to return patients back to preinjury activity levels; however, it does not prevent future post-traumatic osteoarthritis.[4] There have been several studies that have compared ACLR surgical techniques. These include studies comparing all-inside with complete tibial tunnel,[2] using an independent femoral tunnel technique,[5-7] using autografts in younger patients,[1,8] and using a graft greater than 8 mm in diameter.[9-13]

Recent literature has shown that the risk of retear, especially in younger patients, is minimized by the use of bone–patellar tendon–bone (BPTB) grafts rather than other soft-tissue grafts.[14] However, other studies found no differences in graft ruptures with 10-year follow-up[15] and no differences in return to sporting activity[16] when comparing BPTB and hamstring. Residual pain when kneeling has been shown to be significantly greater in

those who underwent ACLR with the use of BPTB grafts than with the use of hamstring autografts.[1,16] Studies looking at BPTB graft use have shown increased long-term anterior knee pain, kneeling pain, and greater rates of osteoarthritis.[17,18]

Studies have not only demonstrated a greater incidence of ACL tears in female patients but have also shown both a greater incidence of retear rates [1,19] and a lower rate of return to sports.[20,21] Female patients often have smaller anatomical knees resulting in smaller notches, tunnel lengths, and autografts for harvest.[22] To avoid a hamstring autograft of inadequate dimensions, and therefore a greater potential chance of failure, a semitendinosus with or without the addition of gracilis can now be quadrupled to ensure a graft diameter ≥ 9 mm. A recent study using a 5-strand graft emphasizes the importance of maximizing graft diameter to a minimum 8 mm to achieve successful ACLR outcomes.[23]

The purpose of this study was to determine 2-year functional outcomes using an all-inside quadrupled semitendinosus ACL reconstruction technique in male and female patients. The authors hypothesized that (1) outcomes would improve and be comparable with traditional techniques in the literature and (2) there would be similar outcomes when comparing male and female patients.

Methods

All patients who had an ACLR were prospectively enrolled in a HIPAA (The Health Insurance Portability and Accountability Act of 1996)-compliant global registry, Surgical Outcome System (Arthrex, Naples, FL). This research study was reviewed by the Committee on Clinical Investigations. Approval by the institutional review board was obtained before the initiation of the present study (#2011P002663). Data were collected prospectively on consecutive surgeries performed by a single surgeon (E.M.) at an academic medical center in an outpatient setting and retrospectively reviewed for the present study. All patients provided informed consent. An a priori power analysis was performed indicating that 100 patients would ensure a sufficient sample size to achieve adequate power for this study.

The initial patient cohort included all patients scheduled for hamstring ACLR using an all-inside quadrupled semitendinosus technique between October 2012 and November of 2017. Patients were excluded if they underwent a revision reconstruction or a multiligament reconstruction. Patients also were excluded if they failed to complete preoperative and both 1- and 2-year postoperative patient-reported outcome measures (PROMs) (Fig 1). All cases were performed using the same surgical technique and postoperative rehabilitation protocol.

All participants were administered a preoperative survey consisting of the following outcome-measuring tools: (1) visual analog scale used to measure overall pain level, (2) the Veterans Rand 12-Item Health Survey (VR-12 Physical and VR-12 Mental),[24] a standard self-reported global health measure tool that is used to assess a patient's overall perspective of their health, (3) the Marx Activity Scale,[25] (4) Knee Injury and Osteoarthritis Outcome Score[26-28] (KOOS) Pain, (5) KOOS symptoms, (6) KOOS Activity of Daily Living (ADL), (7) KOOS Sports and Recreation, (8) KOOS Quality of Life, and (9) Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).[29,30] The same outcome measures were reassessed at 3 months, 6 months, 1 year, and 2 years' postoperatively. Wright[31,32] has previously reported on the validity, reliability, and minimal clinically important difference (MCID) of the Marx Activity, KOOS, and WOMAC outcome measures. For the KOOS domains, participants were categorized by whether an MCID of 8 points was achieved at 2 years postoperatively.[28] Further, at 1 and

Fig 1. Flowchart of patients excluded in study. (ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction.)
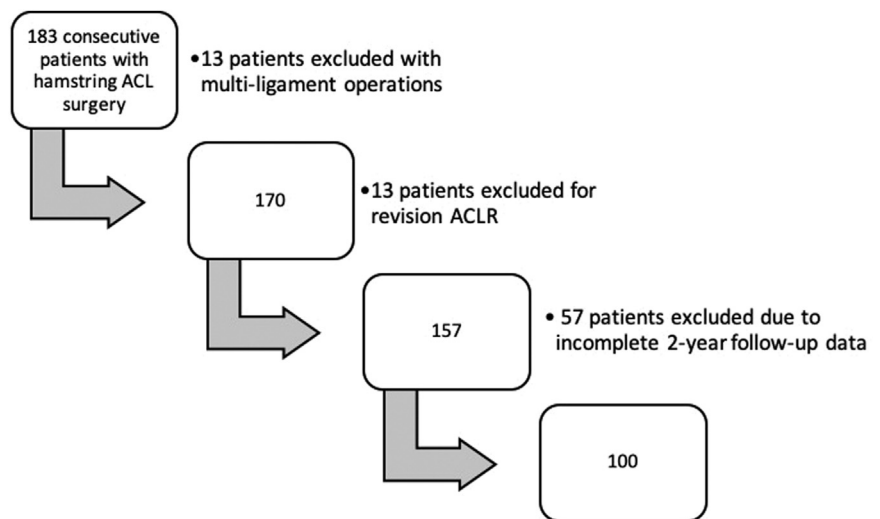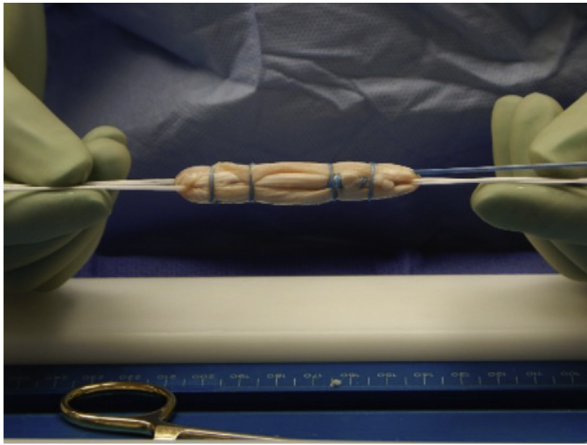
Fig 2. Quadrupled semitendinosus tendon.

2 years' postoperatively, a set of standardized postoperative satisfaction questions was collected. At each time point, participants were e-mailed an electronic survey with one e-mail reminder and one phone call reminder by a research assistant if outcome measures were not completed in a timely manner. All questionnaires were completed electronically, either in clinic or at home.

Surgical Technique

For autograft cases, the semitendinosus was harvested through a small incision centered over the pes anserinus, and for allograft cases, the semitendinosus tendon was defrosted on the back table. Semitendinosus graft lengths were trimmed to 230 to 270 mm depending on patient size and according to predicted graft measurements.[33] A standard quadrupled technique, using adjustable suspensory buttons placed on both ends of the graft was used.[13,33] (Fig 2). Graft diameter was measured to the tightest fit. All graft diameters in this study were a minimum of 9 mm. If the autograft quadrupled semitendinosus was not equal to or greater than 9 mm, the gracilis tendon was harvested and added to the graft to reach a minimum diameter of 9 mm. All allografts used measured 6.5 mm or greater in width resulting in a quadrupled graft diameter of 9 mm or greater.[33]

Standard knee arthroscopy using an anterolateral and anteromedial portal was performed and any meniscal and cartilage pathology was addressed as indicated. An anatomic 30-mm long femoral tunnel was made using an independent femoral guide and a retrograde drilling technique with a diameter equal to that of the graft. An anatomic tibial socket was made in a similar retrograde manner to a length of 35 to 40 mm. The quadrupled semitendinosus graft was shuttled through the anteromedial portal into the knee and the buttons were deployed on both the femoral and tibial sides. The graft was sequentially tightened on each side with approximately 15 to 20 mm of graft in each tunnel until taut.

The knee was cycled multiple times to ensure the graft was tensioned properly.

All patients had an adductor canal block and general anesthesia. All patients were sent home in a postoperative knee brace locked in extension with crutches as needed for ambulation and allowed to weight bear as tolerated once comfortable. The brace was discontinued by 6 weeks postoperatively or when adequate proximal muscle strength was obtained. The same physical therapy rehabilitation protocol was provided to all patients.

Statistical Analysis

Data were summarized with mean and standard deviation (SD) for continuous variables and n (%) for categorical variables. Linear mixed effects models were used to separately assess each PROM over time. For each PROM, change over time and the association between baseline covariates and postoperative PROM were assessed. A sample size of 100 affords the power to detect change over time of approximately 0.33 SDs, e.g., for a PROM with an SD of 10, we are powered to detect changes of ∼3.3 points; for a PROM with an SD of 20, we are powered to detect changes of ∼6.6 points. To assess the association between covariates and PROMs, 100 subjects provides adequate power to detect differences between groups of approximately 0.6 SDs. Analyses were conducted using SAS, version 9.4 (SAS Institute, Cary, NC).

Results

There were 62 female and 38 male patients who met the inclusion criteria and had completed a preoperative, 1-year and 2-year follow-up questionnaire. Study demographics are shown in Table 1. The average age at time of surgery was 31.3 years (range 14-58 years) with an average body mass index of 26.9 (range 19-48.4). The average duration of symptoms until time of surgery was 3.8 months (0.1-36 months).

Sixty-eight patients had concomitant meniscal pathology, of which 23 were medial, 26 were lateral, and 19 were both medial and lateral. Of the patients with meniscal pathology, 62% required a meniscal repair and 38% required a partial meniscectomy. Thirty-one patients had cartilage pathology of which 80% were Outerbridge grade I/II (Table 1). Fifty-four patients received a semitendinosus autograft and 46 received an allograft. The average age of autograft patients was 25 years, and the average age of allograft patients was 36 years. The average age was 32.4 years in male and 30.9 years in female patients ($P = .5634$) (Table 2). The average graft diameter was 9.5 mm (range, 9-11 mm). The average graft diameter for males was 9.8 mm and for females was 9.4 mm ($P = .0003$) (Table 2).

There were 5 female patients, ages 15, 16, 17, 17, and 18 years, whose quadrupled autograft semitendinosus tendon resulted in a graft diameter of less than 9 mm.

Table 1. Demographics, Meniscus, Cartilage, and Graft Characteristics

Variable	n (%)
Sex	
Female	62 (62.0%)
Male	38 (38.0%)
Age group	
30 y or younger	50 (50.0%)
Older than 30 y	50 (50.0%)
BMI category	
Normal weight	41 (41.0%)
Obese	20 (20.0%)
Overweight	39 (39.0%)
Race	
Asian	3 (3.5%)
Asian, Native Hawaiian, or Other Pacific Islander	1 (1.2%)
Black or African American	3 (3.5%)
White	78 (91.8%)
Declined to specify	15
Ethnicity	
Hispanic or Latino	3 (3.1%)
Not Hispanic or Latino	95 (96.9%)
Declined to specify	2
Smoker	
No	98 (99.0%)
Yes	1 (1.0%)
Declined to specify	1
Worker's compensation case	
No	98 (98.0%)
Yes	2 (2.0%)
Diagnoses	
Meniscal tear	
No	32 (32.0%)
Yes	68 (68.0%)
Tear location	
Medial	23 (33.8%)
Lateral	26 (38.2%)
Both	19 (27.9%)
Procedure*	
Repair	38 (62.3%)
Partial meniscectomy	23 (37.7%)
Chondral pathology (Outerbridge grade)	
0	70 (70%)
1	10 (10%)
2	14 (14%)
3	2 (2%)
4	4 (4%)
Graft type	
Autograft	54 (54 %)
Allograft	46 (46%)
Graft diameter, mm	
9.0	47
9.5	5
10.0	42
10.5	2
11.0	4

BMI, body mass index.

*Seven patients had peripheral, stable (<10 mm) tears not requiring any meniscal procedure.

For these patients their gracilis tendon was harvested and a combined semitendinosus and gracilis graft diameter of 10 mm was obtained in 4 patients and 9.5 mm in 1 patient.

All of the outcome scores except for the Marx activity demonstrated functional improvement at both 1 and 2 years' postoperatively when compared with preoperative scores. Table 3 exhibits the mean preoperative, 1-year, and 2-year postoperative scores for visual analog scale, VR-12, MARX activity, KOOS, and WOMAC. The majority of patients achieved MCID in the KOOS domains by 2 years postoperatively: 91% for pain, 80% for symptoms, 77% for ADL, 91% for sport, and 89% for quality of life.

Difference estimates from a linear effects mixed model was also performed looking at multiple variables including age, graft type, graft diameter, and sex. When comparing age (<30 years vs >30 years), the <30-year age group demonstrated significantly greater Marx activity scores at baseline, 1, and 2 years ($P = .02$, .004, .01, respectively). KOOS Sport was also significantly greater at 1 year ($P = .03$) for the <30-year age group.

Similarly, when we compared autograft versus allograft, the autograft group had significantly greater Marx activity scores at baseline ($P = .02$), 1 year ($P = .002$), and 2 years postoperatively ($P = .001$). KOOS Sport at 1 year ($P = .028$) and KOOS ADL at 2 years ($P = .035$) were also significantly greater in the autograft group compared with the allograft group. When comparing graft diameters (<10 mm vs >10 mm), there were no significant differences in VR-12: Physical, Marx activity, KOOS, and WOMAC at 1 or 2 years' postoperatively.

When comparing male and female patients, we found very few differences in outcome scores at baseline, 1 year, and 2 years' postoperatively (Table 4). Differences included a greater Marx activity at 1 year in male patients ($P = .04$) and a greater KOOS ADL at 1 year in female patients ($P = .02$) (Table 4).

Patients' pain expectations were met or exceeded in 94% of cases, and motion and strength expectations were met or exceeded for 91% of cases at 2 years (Table 5). In total, 95% of patient reported expectations were met or exceeded when asked about returning to normal activities. When asked, "how well did the treatment meet your expectations with regard to resuming normal sporting activities?" there were no sex-differences, with 78% of female patients and 79% of male patients meeting or exceeding expectations (Table 5).

Of the 100 patients, 5 required a second surgery on the same or contralateral knee. One male patient had a retear playing lacrosse 17 months after an ACLR with hamstring autograft with a diameter of 10 mm. Three patients had contralateral ACL tears (2 female and 1 male patient). The 2 female patients both tore their contralateral ACL 2 years postoperatively while playing soccer. The male patient had a contralateral right ACL tear 5 years after his left knee ACLR, also playing soccer. One female patient required a repeat arthroscopy for a meniscal tear 4 years after her initial ACLR.

Table 2. Graft Characteristics in Male and Female Patients

Variable	N (%)	Sex, n		Average Age, y*		Average Diameter, mm*	
Male		38		32.4		9.8	
Female		62		30.9		9.4	
Graft Type		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Autograft	54 (54)	22	32	27.8	25.1	9.77	9.47
Allograft	46 (46)	16	30	38.8	37	9.88	9.32

*Age was not significantly different in male versus female patients ($P = .5634$). Average diameter was significantly larger in male versus female patients ($P = .0003$).

Discussion

This study demonstrated that an all-inside quadrupled semitendinosus ACLR technique demonstrated improved outcomes at 1 and 2 years' postoperatively. More importantly, this study showed that patient satisfaction for returning to normal sporting activities were similar between males and females. A total of 78% of female and 79% of male patients reported that ACLR met or exceeded their expectations to return to normal sporting activities.

Patient-reported outcome measures used in this study included measures of symptoms, activity, as well as function. The results of both the current study, as well as earlier literature, have shown ACLR results in significant improvement of symptoms, pain, daily function, and activity level between baseline and 2-years postoperatively.[2,5,7,34]

The Marx activity score decreased from a baseline of 10.98 to 8.75 at 2 years' postoperatively. This is consistent with other studies in the literature. The MOON cohort study demonstrated a Marx activity of 12 at baseline and 9 at 2 years. In the MOON study, 45% of patients returned to the same or greater level of sport at 2 years post-ACLR.[35] In the current study, 79% of male and 78% of female patients reported a return to sporting activities.

Assuming an MCID of 8 for the KOOS, the average improvement in KOOS scores demonstrated clinically meaningful improvements at 2 years' post-ACLR and the majority of patients (>75%) achieved an MCID.[28] Patients' clinical expectations were met or exceeded in 94% of cases when asked about pain, 91% regarding motion and strength, and 95% of patient reported expectations were met or exceeded when asked about return to normal activities.

The <30-year age group demonstrated greater Marx activity and KOOS Sport scores at baseline and 1 year. Correspondingly, the autograft group also demonstrated greater Marx activity scores at all time points as well as a greater KOOS Sport at 1 year and KOOS ADL at 2 years compared with allograft. The average age of autograft patients was 26 versus 38 in allografts, which accounts for the similarities in greater Marx activity scores and KOOS sport scores in the younger age group. The literature has demonstrated a greater risk of retear in younger patients with allograft, and therefore autografts were more often used in younger patients in this cohort.[3,8,36]

Female patients have been shown to have worse outcomes, lower rates of return to sport, and greater risk of retear.[1,14,19-21] Improvements in surgical technique can help ensure female patients have outcomes

Table 3. Outcome Scores: Baseline, 1 Year, 2 Year, and Change From Baseline to 2 Years

PROM	Baseline Mean (SD)	1 Year Mean (SD)	2 Year Mean (SD)	ΔBaseline − 2 Year Estimate (95% CI)	P Value
VAS Pain	3.18 (2.27)	1.23 (1.78)	1.07 (1.86)	−2.10 (−2.67, −1.53)	<.0001
VR-12 Physical	36.35 (9.96)	50.54 (6.75)	52.64 (6.19)	16.16 (13.99-18.34)	<.0001
VR-12 Mental	53.96 (9.16)	55.36 (6.55)	54.65 (8.3)	0.65 (−1.37, 2.66)	.5248
Marx Activity Scale	10.98 (5.27)	7.78 (5.5)	8.75 (5.33)	−2.24 (−3.21, −1.28)	<.0001
KOOS Pain	59.17 (17.27)	87.05 (10.9)	89.03 (11.98)	25.54 (25.64-33.45)	<.0001
KOOS Symptoms	52.64 (18.32)	77.14 (14.24)	80.79 (13.92)	27.95 (23.65-32.25)	<.0001
KOOS ADL	69.38 (19.8)	93.27 (8.42)	95.4 (9.97)	25.69 (21.63-29.76)	<.0001
KOOS Sport/Rec	28.97 (26.3)	73.05 (21.9)	81.25 (19.93)	51.82 (45.67-57.97)	<.0001
KOOS QOL	27.54 (20.31)	64.41 (19.19)	71.56 (21.22)	43.82 (38.40-49.24)	<.0001
WOMAC Pain	71.56 (17.46)	92.42 (8.96)	92.65 (11.2)	20.71 (17.01-24.41)	<.0001
WOMAC Stiffness	60.55 (19.98)	79.08 (15.94)	84.13 (16.46)	23.30 (18.32-28.28)	<.0001
WOMAC Function	69.38 (19.8)	93.27 (8.42)	95.4 (9.97)	25.69 (21.63-29.76)	<.0001

ADL, activities of daily living; CI, confidence interval; KOOS, Knee Injury and Osteoarthritis Outcome Score; PROM, patient-reported outcome measure; QOL, quality of life; SD, standard deviation; VAS, visual analog scale; VR-12, Veterans Rand 12-Item Health Survey; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Table 4. PROMs by Sex at Baseline, 1-Year and 2-Year Time Points

PROM	Timepoint	Female mean (SD)	Male mean (SD)	Mean Difference (95% CI)	*P* Value for Difference
VAS	Baseline	3.14 (2.19)	3.24 (2.42)	−0.09 (−1.03, 0.85)	.85
	1-Year	1.07 (1.74)	1.50 (1.85)	−0.44 (−1.17, 0.30)	.24
	2-Year	1.11 (2.06)	0.99 (1.49)	0.12 (−0.65, 0.88)	.76
VR-12 Physical	Baseline	37.12 (9.91)	35.04 (10.05)	1.97 (−2.18, 6.11)	.35
	1-Year	50.67 (6.97)	50.30 (6.46)	0.48 (−2.35, 3.13)	.74
	2-Year	52.90 (6.53)	52.21 (5.67)	0.69 (−1.85, 3.23)	.59
VR-12 Mental	Baseline	52.62 (9.12)	56.24 (8.88)	−3.78 (−7.51, −0.04)	.05
	1-Year	55.32 (6.77)	55.43 (6.26)	−0.06 (−2.80, 2.68)	.97
	2-Year	53.75 (9.24)	56.12 (6.33)	−2.37 (−5.74, 1.01)	.17
MARX Activity	Baseline	10.74 (5.24)	11.38 (5.36)	−0.50 (−2.68, 1.68)	.65
	1-Year	6.90 (5.42)	9.31 (5.37)	−2.37 (−4.59, −0.16)	.04
	2-Year	8.16 (5.58)	9.71 (4.81)	−1.55 (−3.72, 0.62)	.16
KOOS Pain	Baseline	58.01 (15.78)	61.11 (19.57)	−3.31 (−10.5, 3.91)	.36
	1-Year	88.33 (10.50)	84.84 (11.36)	3.32 (−1.14, 7.78)	.14
	2-Year	89.25 (13.03)	88.67 (10.20)	0.58 (−4.35, 5.50)	.82
KOOS Symptoms	Baseline	52.20 (16.73)	53.37 (20.93)	−1.62 (−9.30, 6.06)	.68
	1-Year	77.98 (13.64)	75.71 (15.32)	1.46 (−4.51, 7.42)	.63
	2-Year	80.47 (14.64)	81.30 (12.82)	−0.82 (−6.54, 4.89)	.78
KOOS ADL	Baseline	68.87 (19.55)	70.22 (20.46)	−1.80 (−10.08, 6.48)	.67
	1-Year	94.88 (7.13)	90.50 (9.78)	4.15 (0.76, 7.54)	.02
	2-Year	95.68 (10.94)	94.93 (8.27)	0.75 (−3.34, 4.85)	.72
KOOS QOL	Baseline	27.92 (21.01)	26.91 (19.35)	0.11 (−8.43, 8.64)	.98
	1-Year	65.31 (20.18)	62.86 (17.54)	1.84 (−6.10, 9.77)	.65
	2-Year	71.57 (22.93)	71.55 (18.36)	0.03 (−8.69, 8.74)	1.00
KOOS Sport	Baseline	26.98 (26.02)	32.29 (26.79)	−5.87 (−16.85, 5.12)	.30
	1-Year	74.57 (22.45)	70.54 (21.04)	3.33 (−5.73, 12.40)	.47
	2-Year	79.58 (21.80)	84.03 (16.26)	−3.99 (−12.22, 4.23)	.34
WOMAC Pain	Baseline	70.75 (16.74)	72.92 (18.76)	−2.34 (−9.65, 4.96)	.53
	1-Year	92.67 (8.95)	92.00 (9.09)	0.78 (−2.94, 4.50)	.68
	2-Year	92.02 (12.82)	93.68 (7.94)	−1.67 (−6.26, 2.92)	.47
WOMAC Stiffness	Baseline	60.21 (17.75)	61.11 (23.49)	−1.31 (−9.69, 7.08)	.76
	1-Year	80.00 (15.30)	77.50 (17.10)	2.08 (−4.56, 8.71)	.54
	2-Year	83.87 (17.29)	84.54 (15.22)	−0.67 (−7.43, 6.09)	.84

ADL, activities of daily living; CI, confidence interval; KOOS, Knee Injury and Osteoarthritis Outcome Score; PROM, patient-reported outcome measure; QOL, quality of life; SD, standard deviation; VAS, visual analog scale; VR-12, Veterans Rand 12-Item Health Survey; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Table 5. Surgical Expectations

2-Year Standard Postoperative Questions	Categories	n (%)
How well did the treatment meet your expectations with regards to your pain level?	Did not meet expectations	6 (6%)
	Met expectations	54 (54%)
	Exceeded expectations	40 (40%)
How well did the treatment meet your expectations with regards to an improvement in motion and strength of the affected joint?	Did not meet expectations	9 (9%)
	Met expectations	49 (49%)
	Exceeded expectations	42 (42%)
How well did the treatment meet your expectations with regards to you resuming normal functions for daily living?	Did not meet expectations	5 (5%)
	Met expectations	53 (53%)
	Exceeded expectations	42 (42%)
How well did the treatment meet your expectations with regard to resuming normal sporting activities?	Did not meet expectations	19 (19%)
	Met expectations	43 (43%)
	Exceeded expectations	27 (27%)
	N/A (not involved in sports)	11 (11%)*

	Female	Male
How Well did the Treatment Meet Your Expectations with Regard to Resuming Normal Sporting Activities?	n (%)	n (%)
Did not meet expectations	12 (21.8%)	7 (20.6%)
Met expectations	23 (41.82%)	20 (58.82%)
Exceeded expectations	20 (36.36%)	7 (20.59%)

N/A, not applicable.
*Eleven patients who did not participate in sports were excluded.

equivalent to male patients. Several studies have demonstrated advantages to using an all-inside quadrupled semitendinosus technique.[2,5,34] One advantage is the use of an independent femoral guide. This allows ease of anatomic placement of the femoral tunnel and increased likelihood of restoring normal knee kinematics, which can be difficult using a trans-tibial technique.[34] It also avoids the potential risks of a short tunnel, posterior wall blowout, and impingement of the lateral wall of the intercondylar notch, often observed when using the anteromedial technique. Having an anatomic femoral tunnel of adequate length is especially important in ACLRs of smaller knees, often encountered in female patients.

Another advantage is the achievable diameter of the quadrupled semitendinosus tendon.[34] As noted in many studies, graft diameter can influence graft strength and anteroposterior stability of the knee, which also will affect the relative risk of failure.[10,34] Recent literature demonstrates that grafts less than 8 mm in diameter increase the risk of retear, especially in younger and female patients.[9-12,19] One study shows that patients with a 9-mm graft were 55% less likely to need a revision ACLR than patients with 7-mm grafts.[37] Further, the likelihood of a revision ACLR was 0.82 times lower for every 0.5-mm increase in graft diameter from 7 to 9 mm.[37] Another study showed that patients were at a 6.8 times greater relative risk of failure if the graft diameter was equal to or less than 8 mm.[38]

A recent study showed that augmenting undersized hamstring autografts with allografts to achieve a minimum of 8 mm diameter led to no difference in revision or failure rate to unaugmented hamstring autografts of similar diameter.[39] This study also showed that there was a statistically significant difference in the proportion of female patients needing allograft augmentation.[39] In this current study, no quadrupled semitendinosus hamstring grafts less than 9mm were used. If the quadrupled semitendinosus graft measured less than 9 mm, graft augmentation was performed and the gracilis was added to the graft to ensure a minimum graft diameter of 9 mm. As previously noted, this was the case for 5 female autograft patients. Graft length and diameter can be accurately predicted based on length and width of the semitendinosus, which can be useful in assuring that the desired dimensions are obtained by surgeons to minimize risk of graft failure.[33]

The ACL tear rate in female athletes ranges between 2.4 and 9.7 times greater than the tear rate in male athletes competing in similar sports.[40] Past studies have shown that after ACLR, females demonstrate increased rates of re-tear, decreased return to the same level of sport compared to males, and overall lower outcome scores.[1,20,21] For many of these athletes, the primary goal of ACLR is return to sport.[41] This increased risk of retear occurs in females both for the index knee as well

as the contralateral knee.[19,42] The difference in outcomes and retear rates between sexes needs to be understood and addressed. The reasons are likely multifactorial to include both surgical technique and postoperative strength/rehabilitation.

By quadrupling the semitendinosus and potentially leveling one aspect of graft retear rates and postoperative outcomes, this study allows for effective comparison between male and female patients as they received grafts of similar diameter (minimum >9 mm). The average graft diameter in female patients was 9.4 mm and male patients 9.8 mm. Although all grafts were above our minimum graft diameter of 9 mm, as recommended in the aforementioned literature, in this cohort, males' average graft diameter was significantly larger than females' average graft diameter ($P = .0003$). Despite this difference, results of this study showed that male and female patients had similar outcome scores, satisfaction, and return to sport after using a quadrupled semitendinosus graft for ACLR. We did not find associations between any baseline covariate and postoperative PROMs; however, we were powered to detect moderate differences and it is possible that small to modest differences between groups were missed.

Limitations

Limitations of this study include selection bias due to incomplete data and limited generalizability, as all surgeries were performed by a single surgeon.

Conclusions

Anatomic all-inside quadrupled semitendinosus ACL reconstruction improves functional outcomes similarly to previous studies between baseline and clinical follow-up at 1 and 2 years' postoperatively and is comparable in both male and female patients.

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