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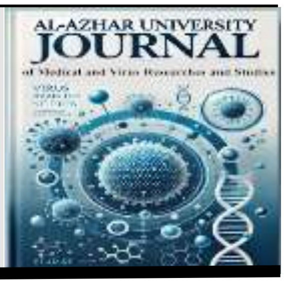

Graft choice For Anterior cruciate ligament Reconstruction Systematic Review

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Abstract

There is no consensus regarding the best graft option for anterior cruciate ligament (ACL) reconstruction. Untreated ACL injury is often associated with instability as well as secondary meniscal and cartilage lesions. Review the evidence about different type of graft for ACL reconstruction to allow the surgeon to take a decision about what is the best graft. We conducted electronic search between January 2010 to March 2021 in different databases; PubMed, SCOPUS, Web of Science, and Cochrane Central Register of Controlled Trials (CENTRAL). We included randomized, nonrandomized trials that were published in English with full text available. We did not restrict our search to the age of gender of the patients. From a total 6912 screened citations, thirty studies met our inclusion criteria with a total 3159 cases. Most of included studies included patellar tendon (PT) and hamstring tendon (HT) while rest of studies evaluated variety of grafts; quadriceps tendon, anterior or posterior tibialis tendon, peroneus longus tendon, and artificial ligaments as alternatives. Both there was no difference between PT and HT autografts groups concerning different scores including Tegner activity score, the Lysholm functional score IKDC subjective and objective, Cincinnati knee, Lachman or pivot shift measurement. However, some evidence suggests that pivot-shift grades were higher in patients undergoing reconstruction with HT, but it had early restoration of activity. PT is associated with early pain and donor site morbidity. It is difficult to reach a solid conclusion for the best graft option, because the published data are heterogeneous in terms of the methodology used and consistency in reporting certain outcomes. However, we provided a comprehensive evaluation for evidence regarding graft options in the literature.

Keywords: Anterior cruciate ligament, patellar tendon, hamstring tendon

1. Introduction

Anterior cruciate ligament (ACL) reconstruction is a common surgery. The aim of surgery is to restore functional stability to the ACL deficient knee. The functional stability provided by the normal ACL is both in resisting anteroposterior translation as well as rotational subluxation. ACL reconstruction can be performed using a variety of different surgical techniques as well as different graft materials.[1] The choice of whether to operate or not is multifactorial and is highly dependent on patient's degree of symptoms and requirements in terms of activity level and participation in pivoting sports.[2] ACL rupture can sometimes be managed conservatively but results are considered better with reconstruction, especially regarding stability, although further trials are ongoing. Non-operative approaches may be considered in lower demand patients but may result in ongoing instability and are not cost-effective in sports people. whereas ACL reconstruction gives good results and allows people to get back to vigorous and pre-injury level of activity .[3]

The surgical technique used during ACL reconstruction varies widely not only from country to country but even within departments of the same hospital. Different techniques include arthroscopic vs open surgery, intra vs extra-articular reconstruction, femoral tunnel placement, number of graft strands, single vs double bundle and fixation method. This heterogeneity of techniques makes comparison of graft choice difficult [4]. The choice of the graft and which technique to use are often dictated to the surgeon by the patient's anatomy, previous surgical history, concomitant injuries, perceived functional outcome, rehabilitation protocol, graft incorporation, graft availability and donor site morbidity. Surgical familiarity also dictates which technique is used as well as the graft choice [5]. The three categories of commonly used grafts are autograft, allograft and synthetic graft. Autografts usually including hamstrings tendons (HS) or Bone-patella tendon-bone peroneus longus tendon (BPTB), and Quadriceps tendon. Allografts are varied include tibialis posterior tendon, Achilles tendon, tibialis anterior tendon, Bone-patellar tendon-bone (BPTB), quadriceps tendon and peroneus longus tendon. [6]. Synthetic grafts have been developed over the years and are currently on their "third generation" but have encountered considerable problems in the past [7]. Currently the most widely accepted synthetics are the Ligament Augmentation Reconstruction System and the Leeds Keio however their use remains somewhat controversial [8]. The aim of this study is to review the different type of graft for anterior cruciate ligament reconstruction which allow the surgeon to take a decision what is the best graft based on current evidence. On systematic review and evidence base.

2. Patients and Methods

We prepared this systematic review with a careful following of the Cochrane Handbook for Systematic Reviews of Interventions. We also adhered to The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines during the design of our study.

2.1 Inclusion criteria

Clinical studies reporting Local graft choice of ACL reconstruction and English literature.

2.2 Exclusion criteria

Case reports, comments, letters, guidelines, protocols, abstracts and review papers, studies with unclear reporting of methods or results and animal and cadaveric studies.

2.3 Literature search

We conducted a literature search between January 2010 till March 2021 using PubMed, Scopus, Web of Science, and Cochrane Library. We performed a search for all published articles that evaluated different graft types for anterior cruciate ligament reconstruction.

We searched article title, abstract, keywords using the following keywords along with "OR" and "AND" operators as following: *("patellar tendon" OR "hamstring tendon" OR "semitendinosus and gracilis tendons" OR "semitendinosus tendon" OR "gracilis tendon" OR "quadriceps tendon" OR "Achilles tendon" OR "posterior tibialis tendon" OR "anterior tibialis tendon" OR "peroneal longus tendon" OR "Leeds-Keio synthetic graft" OR "artificial ligament") AND ("Anterior cruciate ligament reconstruction" OR ACLR)*

The "related articles" function was used to expand the search from each relevant study identified. Bibliographies of retrieved papers were further screened for any additional eligible studies. We searched for articles that were included in previous related systematic reviews. The identified citations were retrieved using Endnote X8 software package (Thompson Reuter, USA).

2.4 Eligibility criteria

We included studies that met our following inclusion criteria:

- **Population:** patients underwent anterior cruciate ligament reconstruction.
- **Intervention:** Any type of graft
- Comparator: Any active comparator
- **Outcome parameters:** safety and efficacy outcomes.
- **Study design:** We limited our search to randomized clinical trials (RCTs) as they are the gold stander in assessment of evidence form the literature.

We excluded animal studies, reviews, book chapters, thesis, editorial letters and papers with overlapped datasets. Eligibility screening was conducted in a two stepwise manner (title/abstract screening and full-text screening). Each step was done by two reviewers independently according to the predetermined criteria.
There were no restrictions on race, sex, or age. The duplicated articles were removed primarily using Endnote X8 program (Thompson Reuter, USA) and manually using titles and abstracts screening

2.5 Data extraction

Data was extracted by two independent authors and revised by two independent authors. We extracted the characteristics of each study as follows: first author, Number of patients, gender, and mean age at surgery, median time from injury to surgery and mean follow-up, additionally we extracted the following scores: Lysholm, Tegner, IKDC Subjective, Cincinnati knee, IKDC Objective scores, Pivot Shift Measurement and Lachman Test.

3. Results

3.1 Result of literature research

We obtained 1,526 articles from PubMed, 2,128 articles from Scopus, 1,529 articles from Cochrane library and 1,729 from web of science (a total of 6912). 2859 duplicated articles were removed using Endnote X8 program (Thompson Reuter, USA), 4053 articles manually underwent titles and abstracts screening, and 208 articles underwent full-text review as shown in figure 1. 30 studies finally met our inclusion criteria.

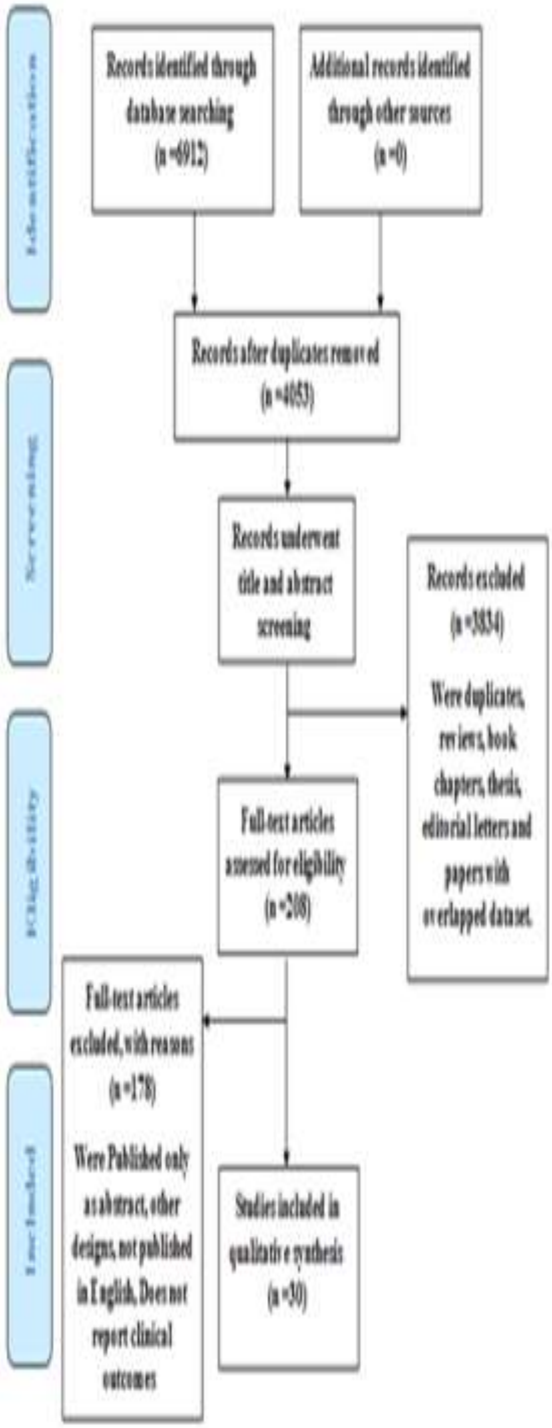

Figure (1): PRISMA flow diagram showing process of studies selection.

3.2 Characteristics of included studies

As shown in Table .1 we identified 30 studies that evaluated different graft types for anterior cruciate ligament reconstruction with a total of 3159 cases. Mean age of patients across the studies ranged between 20 and 30 years. There was male predominance in the included cases**.** Mean follow-up across the studies ranged between 1 year and 15 years. Rest of included studies characteristics are summarized in Table 1.

3.2 Patellar tendon autograft versus Hamstring tendon autograft

As show in table 2 ten studies compared Patellar tendon autograft versus Hamstring tendon autograft with a total of 1155 cases. In patellar tendon group compared to hamstring tendon group, Lysholm score range was (84.2 - 92.84) vs. (86.1- 93), Tegner score range was (4.3 - 6.5) vs. (4-6.4), IKDC subjective score range was (1.8 - 84.6) vs. (2.2- 85.3), Cincinnati knee score range was (36.8 - 91) vs. (34.4- 89.3), normal IKDC objective score range was (0% - 92%) vs. (0%- 82%), Equal Pivot Shift Measurement range was (32% - 80%) vs. (25%- 72%) and normal Lachman Test was (62% - 66.7%) vs. (32%- 67%).

3.3 Rest of Graft types

From Table 3 to Table 7, we summarize reports for each graft. In Semitendinosus and gracilis tendons group compared to gracilis tendons group, Lysholm score was 85.3 vs. 86.2 and IKDC subjective score was 80.8 vs. 83.5. This might suggest that the addition of Semitendinosus tendon to gracilis tendon might not be of clinical value, however, this result is based on only one study.

In Hamstring Tendon allograft group compared to Patellar tendon allograft group, Lysholm score was 93.7 vs. 92.6, IKDC subjective score was 89.5 vs. 88.3, Equal Pivot Shift Measurement was (74% - 90.3%) vs. (75%- 82%) and normal Lachman Test was 93.4% vs. 88.5%. In Patellar tendon allograft group compared to Hamstring Tendon allograft group, Lysholm score was 90.1 vs. 87.3, IKDC subjective score was 89.9 vs. 87, and normal Lachman Test was 88% vs. 70%.

In Single-bundle modified patellar tendon group compared to Double-bundle tibialis anterior allograft group, Lysholm score was 93.2 vs. 94, Tegner score was 7 vs. 7, IKDC subjective score was 89.9 vs. 91.1, Equal Pivot Shift Measurement was 79% vs. 85% and normal Lachman Test was 84% vs. 85%.

In Hamstring Tendon autograft group compared to Free tendon Achilles allograft group, Lysholm score was 98 vs. 99, Tegner score was 6 vs. 6, normal IKDC objective score was 69.7% vs. 59.4%, Equal Pivot Shift Measurement was 81.8% vs. 81.3% and normal Lachman Test was 81.8% vs. 65.6%.

In Double-strand peroneus longus tendon group compared to Hamstring Tendon autograft group, Lysholm score was 94 vs. 93, Tegner score was 5 vs.6, IKDC subjective score was 90.13 vs. 89.22, and normal Lachman Test was 87% vs. 88%.

In 5-strand hamstring grafts group compared to 4-strand hamstring grafts group, Lysholm score was 94.7 vs. 90.8., Tegner score was 5.92 vs. 6.21, IKDC subjective score was 70.7 vs. 67.7, Equal Pivot Shift Measurement was 0% vs. 0% and normal Lachman Test was 0% vs. 0%.

In Quadriceps Tendon autograft group compared to Patellar Tendon autograft group, Lysholm score was 95.6 vs. 95.2, Tegner score was 6 vs. 6, IKDC subjective score range was (70 - 92) vs. (84- 91), Cincinnati knee score was (88 - 91) vs. (85-90), normal IKDC objective score was (33% - 35.5%) vs. (29%- 37%), Equal Pivot Shift Measurement was (91.7% - 95.2%) vs. (61.3%- 94.9%) and normal Lachman Test was (80.6% - 87.1%) vs. (32.3%-86.4%).

In view of the above, our study includes variety of grafts, but there is a lack of direct comparison between most of the grafts in order to justify the superiority of certain graft over the others. However, we identified some important findings; PT and HT autografts had comparable results, but it had early restoration of activity, while PT is associated with early pain and donor site morbidity. Peroneus longus tendon had good results and should be taken into consideration. We also investigated the efficacy of other grafts but there are limited data to support their usage such as Leeds-Keio synthetic graft, double-bundle tibialis anterior allograft, Iliotibial band autograft and quadriceps Tendon autograf

Table 1: Characteristics of included studies:

Study ID	Design	N	Type of graft	N for each group	Age (years) Mean, SD\Range	Gender (women /men)	Median time from injury to surgery months	follo w up
Drogset et al. [9]	Randomized Study	115	Patellar tendon autograft	58	26 (18–49)	----------	13 (2–180) months	Two years
			Hamstring tendon autograft	57	27(18–50)		12 (0–240) months	
Holm et al. [10]	Randomized Study	72	Patellar tendon autograft	28	25 (7)	10/18	41.3 (41.0) months	10.2 (0.4)
			Hamstring tendon autograft	29	27 (9)	14/15	40.5 (41.6) months	10.7 (0.4)
Kautzner et al. [11]	Randomized Study	150	Patellar tendon autograft	74	26 (17–47)	----------	----------	one year
			Hamstring tendon autograft	73				

Leitgeb et al. (12)	Non-randomized Study	96	Patellar tendon autograft	56	----------	----------	----------	5-year
			Hamstring tendon autograft	40				
Mohtadi et al. (13)	Randomized Study	220	Patellar tendon autograft	110	28.7	47\63	----------	2-Year
			Hamstring tendon autograft	110	28.5	51\59		
Razi et al. (14)	Non-randomized Study	71	Patellar tendon autograft	46	30.8±4.5	8\38	----------	3
			Hamstring tendon autograft	41	28.2±3.7	5\36		
Barenius et al. (15)	Randomized Study	153	Patellar tendon autograft	78	33 (6.3)	\38	----------	8-years
			Hamstring tendon autograft	75	35 (7.5)	\51		

Konrads et al. (16)	Randomized Study	62	Patellar tendon autograft	31	----------	----------	----------	10 years
			Hamstring tendon autograft	31				
Gupta et al. (17)	Randomized Study	42	Patellar tendon autograft	21	25.9 ±6.19	----------	----------	1 year
			Hamstring tendon autograft	21	25.8 ±7.54			
Smith et al. (18)	Randomized Study	64	Patellar tendon autograft	32	17.7 ± 2.4	17\15	(11-340) days	2- years
			Hamstring tendon autograft	32		19\13		
Sun et al. (19)	Randomized Study	186	Hamstring Tendon Autograft	91	29.6 ± 6.9	20\ 71	2.3 ± 1.1 (0.5-7.5) months	7.6
			Hamstring Tendon Allograft	95)	31.2 ± 8.3	17\ 78	2.5 ± 1.8 (0.6-9.6) months	7.9

Sun et al. [20]	Randomized Study	67	Hamstring Tendon Autograft	36	30.9 ± 8.7	8 \28	1.6 ± 1.3 (0.5-5.5) months	2.5 Years
			Hamstring Tendon Allograft	31	30.3 ± 7.9	7 \24	1.8 ± 1.3 (0.5-5.2) months	
Tian et al. [21]	Randomized Study	83	Hamstring Tendon Autograft	40	29.2 ± 6.9	8\32	1.5 ± 1.1 (0.3-6.5) months	7
			Hamstring Tendon Allograft	43	28.6 ± 7.2	9\34	1.6 ± 1.2 (0.5-7.0) months	6.8
Tian et al. [22]	Randomized Study	157	Hamstring Tendon Autograft	62	----------	----------	----------	
			Hamstring Tendon Allograft	59				
Ghalayini et al. [23]	Randomized Study	50	Patellar tendon autograft	26	30.9 (28.1–33.6)	7\19	33 (19–47) months	Five years
			Leeds-Keio synthetic graft	24	31.7 (29.0–34.5)	3\21	55 (35–75) months	

Karimi-Mobarakeh et al. (24)	Randomized Study	19	Semitendinosus and gracilis tendons	----------	29.7 ± 7.9	11\	2. 7 ± 1.9 months	1-year
			Semitendinosus only		28.8 ± 8.2	10\	2.8 ± 1.6 months	
Lawhorn et al. (25)	Randomized Study	174	Hamstring Tendon Autograft	74	32	22\32	----------	2 Years
			Tibialis anterior tendon allograft	73	33.3	10\38		
Sun et al. (26)	Randomized Study	424	double-bundle technique with autograft	154	27.5 (19–52)	48\106		3 Years
			double-bundle technique with allograft	128	27.1 (19–50)	34\94	----------	
			single-bundle technique with allograft	142	28.2 (19–52)	41\101		
Dai et al. (27)	Randomized Study	129	Hamstring Tendon allograft	61	30 ± 6	25\36	10 ± 7 (5–25)	4 Year

			Patellar tendon allograft	52	29 ± 5	17\35	8 ± 6 (2–29)	
Niu et al. [28]	Randomized Study	101	Patellar tendon allograft	50	26 ± 5	25\25	12 ± 6 (weeks)	3 Years
			Hamstring Tendon allograft	51	27 ± 4	24\27	13 ± 5(weeks)	
Bottoni et al. [29]	Randomized Study	97	Hamstring Tendon autograft	48	28.9 ±5.8	7/41	----------	10-Year
			Tibialis posterior allograft	49	29.2 ±5.5	6/43		
Kang et al. [30]	Randomized Study	94	Single bundle modified patellar tendon	43	30 ±5	23\20	9 ±6 (weeks)	3 Years
			double-bundle tibialis anterior allograft	41	28 ± 5	20\21	10 ± 5(weeks)	
Lund et al. [31]	Randomized Study	51	Quadriceps Tendon autograft	----------	30± 9	----------	15 ± 31 months	2-year

			Patellar Tendon autograft		31 ±8		21 ± 41 months	
Noh et al. [32]	Randomized Study	65	Hamstring Tendon autograft	33	23 (20–51)	3\30	7.2 ± 10.3 (weeks)	2-year
			Free tendon Achilles allograft	32	22 (20–55)	6\26	6.5 ± 8.2 (weeks)	
Shi et al. [33]	Non-randomized Study	38	Double-strand peroneus Longus tendon	----------	----------	----------	----------	----------
			Hamstring Tendon autograft					
Stensbirk et al. [34]	Randomized Study	60	Iliotibial band	25	26 (14–37)	10\15	39 (7-169) months	15-years
			Patellar tendon	24	30 (18–44)	7\17	29.5 (1-144) months	
Smith et al. [18]	Randomized Study	64	Patellar tendon autograft	32	17.7 ± 2.4	17\15	1(1-340) days	2-year

			Hamstring tendon autograft	32		19\13		
Sinding et al. [35]	Randomized Study	85	quadriceps tendon autograft	42	28.7 (6.4)	17\25	14.4 (20.5) months	1 year
			semitendinosus-gracilis autograft	43	28.3 (6.2)	20\23	14.6 (15.1) months	
Krishna et al. [36]	Randomized Study	64	5-strand hamstring grafts	28	26.3 ± 7.3	5\ 23	16.8 (1-93) months	2-year
			4-strand hamstring grafts	28	27.6 ± 7.3	8\20	8.6 (1-72) months	
Barié et al. [37]	Randomized Study	60	Quadriceps tendon autograft	30	----------	13\17	1.8 ± 3.12 years	10 years
			patellar tendon autograft	30		13\17	1.4 ± 2.43 years	

Table 2: Patellar tendon autograft versus Hamstring tendon autograft

Study ID	Patellar tendon autograft				Hamstring tendon autograft			
	Lysholm score (0-100)							
Drogset et al. [9]	91(±10.2, 30–100)				91 (±10.3, 12–100)			
Holm et al. [10]	84.2 (±15.4)				86.1 (±15.1)			
Kautzner et al. [11]	88 (±7.5)				90 (±7.6)			
Barenius et al. [12]	88 (43-100)				89 (40-100)			
Konrads et al. [13]	92				91.8			
Gupta et al. [14]	92.84 ± 2.630				93 ± 1.862			
Study ID	Tegner score (1-10)							
Drogset et al. [9]	no significant differences							
Holm et al. [10]	4.3 (±2.2)				4.8 (±2.3)			
Mohtadi et al. [13]	6.5 (±1.8)				6.4 (±2.0)			
Barenius et al. [15]	5 (0-10)				4 (1-9)			
Konrads et al. [16]	5.9				5.1			
Study ID	IKDC Subjective Score							
Mohtadi et al. [13]	84.6 (±13.8)				85.3 (±11.6)			
Konrads et al. [16]	1.8				2.2			
Study ID	Cincinnati knee score (0-100)							
Holm et al. [10]	84 (± 14.5)				87.8 (± 12.3)			
Mohtadi et al. [13]	36.8 (± 19.4)				34.4 (±22.1)			
Gupta et al. [17]	91 (± 4.1)				89.3(± 5.3)			
	IKDC Objective Score							
Study ID	A (normal)	B (nearly normal)	C (abnormal)	D (severely abnormal)	A (normal)	B (nearly normal)	C (abnormal)	D (severely abnormal)
Leitgeb et al. [12]	27 (48)	25 (44)	2 (4)	2 (4)	12 (30)	20 (50)	6 (15)	2 (5)
Mohtadi et al. [13]	12(10)	65(59)	23(20)	1(1)	12(10)	62(56)	28(25)	2(2)
Razi et al. [14]	34(92)		3(8)		28(82)		6(18)	
Barenius et al. [15]	7 (9)	45 (58)	16 (20)	10 (13)	11(15)	36(48)	21 28)	7(9)
Smith et al. [18]	0 (0)	1 (3)	14 (44)	17 (53)	0 (0)	0 (0)	14 (44)	18 (56)
Study ID	Pivot Shift Measurement							
	Equal	Glide (+)	Clunk (++)	Gross (+++)	Equal	Glide (+)	Clunk (++)	Gross (+++)
Mohtadi et al. [13]	36(32)	52(47)	14(12)	0 (0)	28(25)	57(51)	18(16)	1(1)
Razi et al. [14]	29(79)	6(16)	2(5)	0 (0)	15(44)	12(35)	7(21)	0 (0)
Barenius et al. [15]	62 (80)	12 (15)	1 (1)	0 (0)	54 (72)	19 (25.3)	1 (1.3)	1 (1.3)
Study ID	Lachman Test							

	Normal	1+	2+	3+	Normal	1+	2+	3+
Razi et al. [14]	23(62)	11(30)	3(8)		11(32)	18(53%)	5(15%)	
Barenius et al. [15]	48 (61)	28 (36)	0 (0)	2 (3)	50 (67)	21 (28)	3 (4)	1 (1)
Konrads et al. [16]	16(66.7)	8 (33.3)	0 (0)	0 (0)	12(52.2)	9(39.1)	1(4.4)	1(4.4)

Table (3): Lysholm score

Study ID	Lysholm score (0-100)	
	Semitendinosus and gracilis tendons	gracilis tendons
Karimi-Mobarakeh et al. [23]	85.3 ± 4.9	86.2 ± 4.6
	Hamstring Tendon allograft	Patellar tendon allograft
Dai et al. [26]	93.7 ± 6.1	92.6 ± 5.2
	Patellar tendon allograft	Hamstring Tendon allograft
Niu et al. [27]	90.1 ± 5.1	87.3 ± 4.6
	Single-bundle modified patellar tendon	double-bundle tibialis anterior allograft
Kang et al. [29]	93.2 ± 5.0	94.0 ± 4.8
	Hamstring Tendon autograft	Free tendon Achilles allograft
Noh et al. [31]	98 (85–100)	99 (85–100)
	Double-strand peroneus longus tendon	Hamstring Tendon autograft
Shi et al. [32]	94 ± 6.81	93 ± 5.22
	5-strand hamstring grafts	4-strand hamstring grafts
Krishna et al. [35]	94.7 ± 6.7	90.8 ± 8.60
	Quadriceps Tendon autograft	Patellar Tendon autograft
Barié et al. [36]	95.6 ± 7.8	95.2 ± 6.6

Table 4: IKDC Subjective Score

Study ID	IKDC Subjective Score		
	Semitendinosus and gracilis tendons	gracilis tendons	
Karimi-Mobarakeh et al. [23]	80.8 ± 6.8	83.5 ± 6.3	
	double-bundle technique with autograft	double-bundle technique with allograft	single-bundle technique with allograft
Sun et al. [25]	92.9 ± 4.3	93.7 ± 4.0	92.7 ± 4.3
	Hamstring Tendon allograft	Patellar tendon allograft	
Dai et al. [26]	89.5 ± 5.6	88.3 ± 5.2	
	Patellar tendon allograft	Hamstring Tendon allograft	
Niu et al. [27]	89.9 ± 5.2	87.0 ± 5.0	
	Hamstring Tendon autograft	Tibialis posterior allograft	
Bottoni et al. [28]	77.2 ± 25.4	73.7 ± 25.9	
	Single-bundle modified patellar tendon	double-bundle tibialis anterior allograft	
Kang et al. [29]	89.9 ± 4.7	91.1 ± 5.6	
	Quadriceps Tendon autograft	Patellar Tendon autograft	
Lund et al. [30]	70 ± 16	84± 13	
Barié et al. [36]	92 ± 11.5	91 ± 7.3	
	Double-strand peroneus longus tendon	Hamstring Tendon autograft	
Shi et al. [32]	90.13 ± 3.01	89.22 ± 3.83	
	5-strand hamstring grafts	4-strand hamstring grafts	
Krishna et al. [35]	70.7 ± 5.8	67.7 ± 7.9	

Table 5: IKDC objective score

Study ID	IKDC											
	A (normal)	B (nearly normal)	C (abnormal)	D (severely abnormal)	A (normal)	B (nearly normal)	C (abnormal)	D (severely abnormal)	A (normal)	B (nearly normal)	C (abnormal)	D (severely abnormal)
	double-bundle technique with autograft				double-bundle technique with autograft				single-bundle technique with allograft			
Sun et al. (25)	119	30	5	0 (0)	98	24	6	0 (0)	110	25	7	0 (0)
	four-stranded autogenous hamstring Tendon				two-stranded free tendon Achilles allograft							
Noh et al. (31)	23 (69.7)	7 (21.2)	3 (9.1)	0 (0)	19 (59.4)	7 (21.9)	6 (18.6)	0 (0)				

Table 6: Pivot Shift Measurement

Study ID	Pivot Shift Measurement							
	Equal	Glide (+)	Clunk (++)	Gross (+++)	Equal	Glide (+)	Clunk (++)	Gross (+++)
	Hamstring Tendon allograft				Patellar tendon allograft			
Dai et al. (26)	56 (90.3)	5 (9.7)	0 (0)	0 (0)	39 (75)	8 (15.4)	5 (9.6)	0 (0)
Niu et al. (27)	35 (74)	8 (17)	4 (9)	0 (0)	40 (82)	8 (16)	1 (2)	0 (0)
	Single bundle modified patellar tendon				double-bundle tibialis anterior allograft			
Kang et al. (29)	34 (79)	8 (19)	1 (2)	0 (0)	35 (85)	6 (15)	0 (0)	0 (0)
	Hamstring Tendon autograft				Free tendon Achilles allograft			
Noh et al. (31)	27 (81.8)	5 (15.2)	1 (3)		26 (81.3)	3 (9.4)	3 (9.4)	
	5-strand hamstring grafts				4-strand hamstring grafts			
Krishna et al. (35)	0 (0)	4 (14.3)	24 (85.7)	0 (0)	0 (0)	3 (10.7)	25 (89.3)	0 (0)

Table (6): Lachman Test

Study ID	Lachman Test							
	Normal	1+	2+	3+	Normal	1+	2+	3+
	Hamstring tendon allograft				Patellar tendon allograft			
Dai et al. (26)	57 (93.4)	4 (6.6)	0 (0)	0 (0)	46 (88.5)	3 (5.7)	3 (5.8)	0 (0)
	Patellar tendon allograft				Hamstring Tendon allograft			
Niu et al. (27)	43 (88)	5 (10)	1 (2)	0 (0)	33 (70)	9 (19)	5 (11)	0 (0)
	Single bundle modified patellar tendon				double-bundle tibialis anterior allograft			
Kang et al. (29)	36 (84)	5 (12)	2 (5)	0 (0)	35 (85)	3 (7)	3 (7)	0 (0)
	Hamstring Tendon autograft				Free tendon Achilles allograft			
Noh et al. (31)	27 (81.8)	5 (15.2)	1 (3)	0 (0)	21 (65.6)	8 (25)	3 (9.4)	0 (0)
	Double-strand peroneus longus tendon				Hamstring Tendon autograft			
Shi et al. (32)	14(87)	4(13)	0 (0)	0 (0)	16(88)	2(6)	2(6)	0 (0)
	5-strand hamstring grafts				4-strand hamstring grafts			
Krishna et al. (35)	0 (0)	3 (10.7)	25 (89.3)	0 (0)	0 (0)	4 (14.3)	23 (82.1)	1 (3.6)

4. Discussion

Zlotnicki et al. stated that the anterior cruciate ligament (ACL) is one of the key components that maintain knee joint stability. The incidence rate of ACL injury has been rapidly rising with the introduction of high-level sports-related activities. [37] Gans et al. It is estimated that the incidence of ACL ruptures is estimated to range from 30 to 78 per 100,000 person-years. [38] Paschos observed untreated ACL injuries are associated with high incidence of knee osteoarthritis. Recent evidence suggests that surgical management of ACL injuries prevents development of knee osteoarthritis besides improvement in knee kinetics [39].

Bonnin et al. stated that surgical reconstruction of the ACL is considered the treatment of choice, and it is a critical step in returning individuals to function after injury. However, there is no gold standard treatment protocol that has been identified for ACL reconstruction.[40] Sun et al. stated that the outcome of ACL reconstruction is highly dependent on the type of graft used. However, literature showed unresolved controversy over the choice of graft tissue [41].

Middleton et al. stated that the ideal graft material should have easy accessibility, little donor site morbidity, immediate rigid fixation, and rapid wound healing. There are variety of grafts that have been proposed including patellar tendon, hamstring tendon, quadriceps tendon, anterior or posterior tibialis tendon, peroneus longus tendon, and artificial ligaments [42].

Hence, we conducted this study to evaluate the evidence from the literature regarding different types of grafts for ACL reconstruction in order to allow the surgeon to take a decision what is the best graft could be used.

In clinical practice, patellar tendon (PT) and hamstring tendon (HT) autografts are the most common and traditional choices. Nevertheless, they have some advantages and disadvantages. Benner et al. stated that Regarding PT, disruption of the extensor mechanism may develop following harvesting PT graft [43]. Lee et al. stated that rupture of PT may occur that require surgical intervention, however it is a rare complication. Oliveira et al. [44] stated that during ACL reconstruction, graft-tunnel mismatch is a potential problem with the central third of the patellar tendon, especially with single-incision technique. This is due to the graft being too long to fit appropriately in relation to the tunnels that have been created [45].

Samuelsson et al. stated that regarding HT, unlike PT, HT spares the extensor mechanism. However, there are many concerns regarding HT including failure to achieve immediate rigid fixation to bone, low stiffness, risk of increased laxity, bone tunnel enlargement, [46] Segawa et al. stated that weakness of the hamstring musculature with difficulties controlling internal tibial rotation, slower soft tissue–bone healing and reduced strength in deep flexion [47].

Barker et al.; Heijne and Werner; Persson et al. stated that there are many advantages for both grafts. PT is preferred over HT by many surgeons due to its higher stability, lower revision rate, lower incidence of deep infections, lower graft failure, and less tunnel enlargement. (48-50) Genuario et al.; Goldblatt et al. On the other hand, HT is cost-effective, has a low OA rate, less anterior knee problems, lower and less extension loss [51,52].

The superiority of one over the other is a matter of debate as each graft has its own pros and cons as shown above. In this study, there was no difference between the groups concerning different scores including Tegner activity score, the Lysholm functional score IKDC subjective and objective, Cincinnati knee, Lachman or pivot shift measurement.

However, Razi et al. stated that pivot-shift grades were higher in patients undergoing reconstruction with HT compared to PT suggesting that increased stability with the use of PT graft in reconstruction of ACL [14]. In Gupta et al. mention that overall activity in the Cincinnati score at six months, HT group were significantly better than the patients in the PT group but, this difference was no longer significant at one year follow-up that indicates early return to sports in HT group [17].

On the long term, in both HT and PT, there was a tendency of worsening over time IKDC scores after 5- and 10-years post-surgery, especially in the HT group. Moreover, Konrads et al. found both HT and PT performed equally with similar degenerative changes on the long term follow up, this was confirmed by radiological degenerative changes after 10 years of follow-up, suggesting the beginning of posttraumatic arthritis. (16)

Our findings are consistent with previous systematic reviews. He et al. reported that PT was associated with increased frequency of donor-site complications. HT had lower knee stability, but this was only in the long term, and it could be improved by more rehabilitation protocols [53]. Chen et al. reported that both types of grafts had had comparable results in terms of knee stability, functional outcomes, knee stability over the mid and long term. However, PT group was associated with significantly higher risk of anterior knee pain [54].

Edgar et al. reported that allograft is another graft option that gained interest over those last few years. As it does not carry the risks that are associated with autograft such as additional scars, harvest-site morbidity, neuromas, and the possibility of harvested tissue being insufficient for repair [55].

Beer et al.; Doral et al. reported that allograft has the advantages of absence of donor-site morbidity, sparing extensor or flexor muscles, better cosmetic result, easier rehabilitation, lower incidence of postoperative arthrofibrosis, more suitable for multiple ligamentous injury and availability of larger grafts that makes them suitable for revision surgery. Many allograft tissues have been introduced; PT, HT, Achilles tendon, tibialis tendon, and peroneus longus tendon [5,6,7].

Gobbi et al. reported that another factor that discussed was whether to use double-bundle ACL reconstruction instead of single-bundle ACL reconstruction in order to improve terms of anteroposterior laxity, rotational stability as double-bundle technique includes both anteromedial and posterolateral bundles which restore anterior and rotational stability of the knee [58]. Tian et al. reported that double-bundle technique did not cover the biomechanical defect in radiated HT graft. (20) However, in Sun et al. reported that double-bundle technique had better stability along with lower rates of tunnel expansion using both allogradt and autograft compared to single-bundle with autograft [25].

Two studies compare HT allograft to PT allograft. Dai et al. reported that HT allograft achieved superior anteroposterior and rotational stability [26]. On the contrary, Niu et al. reported PT allograft was better regarding IKDC, Lysholm scores and rates of graft failure [27]. This is due to graft modifications used by the authors; Dai et al. used 6-strand HT allograft not 4-strand HT allograft as in Niu et al. while Niu et al. reported that the used double-layer PT allograft not traditional PT allograft as in Dai et al [26,2].

Bottoni et al. reported that HT and PT grafts were compared to less commonly reported grafts in the literature. HT autograft was compared to tibialis posterior allograft, [28] Noh et al. reported that the free tendon Achilles allograft, [31] and Shi et al. double-strand peroneus longus tendon. [32] Bottoni et al. reported that all three grafts were suitable alternative to HT autograft achieving comparable clinical or functional scores. Apart from tibialis posterior allograft which had higher graft failure (8.3% vs., 26.5%) [28].

Ghalayini et al. reported that PT autograft was also compared to Leeds-Keio synthetic graft,[22] Kang et al. double-bundle tibialis anterior allograft,[29] Stensbirk et al. reported that the iliotibial band autograft [33] and Barié et al.; Lund et al. reported that the quadriceps Tendon autograft [36,30]. All of these grafts had comparable clinical or functional scores to PT autograft making them valid options. It should be noted that QTB autograft had lower donor site morbidity such as kneeling pain, graft site pain, and sensitivity loss. Kang et al. reported that the compared double-bundle tibialis anterior allograft to double-layer PT allograft, both achieved similar clinical outcomes [29].

5. Conclusion

It is difficult to reach a solid conclusion for the best graft option, because the published data is heterogeneous in terms of the methodology used and consistency in reporting certain outcomes. However, we provided a comprehensive evaluation for evidence regarding graft options in literature.

RECOMMENDATIONS

PT tendons could be used in high athletes, professional athletes and in pivoting sports. Extra-articular HT showed efficacy in patients with generalized high laxity and high grads pivot shift. QT is one of the most common grafts used in revision surgery.
Peroneus longus tendon grafts had promising results in ACL reconstruction if there was proper patient selection.

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