

Return-to-Sport Outcomes After Primary Ulnar Collateral Ligament Reconstruction With Palmaris Versus Hamstring Tendon Grafts

A Systematic Review

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Background: Ulnar collateral ligament (UCL) reconstruction is the current gold standard of treatment for overhead athletes with a symptomatic, deficient UCL of the elbow who have failed nonoperative treatment and wish to return to sport (RTS) at a high level. The palmaris longus and hamstring tendons are common graft choices, but no study has analyzed the existing literature to assess whether one graft is superior to the other.

Purpose: To systematically report on the outcomes of UCL reconstruction using palmaris and hamstring autografts.

Study Design: Systematic review; Level of evidence, 4.

Methods: A combination of the terms “ulnar collateral ligament,” “valgus instability,” “Tommy John surgery,” “hamstring,” and “palmaris longus” were searched in PubMed, Embase, and the Cochrane Library. RTS and return-to-same-level (RSL) rates, patient-reported outcomes, and complications were included for analysis. We used the modified Coleman Methodology Score and risk-of-bias tool for nonrandomized studies to assess the quality of the included studies.

Results: This review included 6 studies (combined total of 2154 elbows) that directly compared palmaris and hamstring graft use in UCL reconstruction. Follow-up ranged from 24 to 80.4 months, and the mean patient age across all studies was 21.8 years. The mean RSL across all studies and grafts was 79.0%, and the mean RTS was 84.1%, consistent with results previously reported in the literature. The mean RTS and RSL rates for the palmaris graft group were 84.6% and 82%, respectively; the hamstring graft group showed mean RTS and RSL rates of 80.8% and 80.8%. Meta-analysis revealed no significant difference in RSL between the 2 graft groups (odds ratio, 1.06; 95% CI, 0.77-1.46). The combined complication rate of the included studies was 18.2%, with failure rates ranging from 0% to 7.1%.

Conclusion: Results of this review indicated that both palmaris and hamstring tendon grafts are viable options for primary UCL reconstruction. Graft choice should be determined by a combination of patient and surgeon preference.

Keywords: hamstring; palmaris longus; return to sport (RTS); Tommy John surgery; ulnar collateral ligament

Athletes performing overhead activities are commonly exposed to valgus forces at the elbow. Multiple anatomic structures provide stabilization against these forces, with the ulnar collateral ligament (UCL) providing the greatest contribution.^{6,14,21} Repetitive valgus stress at the elbow, particularly in overhead athletes, can result in acute or

chronic tears of the UCL that destabilize the elbow, leading to pain, decreased athletic performance, and subsequent injury to surrounding soft tissues and osseous structures.⁵ Clinical management of these lesions was revolutionized in 1986, when Dr Frank Jobe described surgical reconstruction of the UCL (UCLR) using palmaris tendon grafts in 16 athletes, the majority of whom were able to return to their sport.¹⁶ Jobe’s technique transformed the management of valgus instability at the elbow, providing injured athletes a surgical solution with high rates of return to play.¹

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Despite its success, Jobe's original approach to UCLR was associated with complications, such as postoperative ulnar neuropathy, which necessitated the development of alternative methods. An early advancement was the modified Jobe technique, which longitudinally split the flexor-pronator mass rather than detaching it from the medial epicondyle; in addition, the proximal humeral tunnels were moved anteriorly, and routine ulnar nerve transposition was no longer required.^{15,28,30} The docking technique, which utilized a triangular graft construct to reduce humeral bone loss and improve tensioning and fixation of the graft, marked another important evolution in care.^{15,25} Both techniques resulted in improved outcomes and decreased complications.³¹ A 2016 survey of Major League Baseball (MLB) team physicians indicated that the modified Jobe and docking techniques were the most commonly performed techniques, and the palmaris longus tendon was their preferred graft choice.¹⁰ The palmaris longus is not always available for use, however, as the muscle is congenitally absent in up to 16% of the population.²⁹ The most common alternative autograft option when the palmaris tendon is not available is hamstring autograft, with recent work showing that it can be sourced from either leg without affecting return to sport (RTS) or performance.⁹

The palmaris longus and hamstring tendons have proven viable graft options leading to successful outcomes after UCL reconstruction, and the body of literature reporting the outcomes following the use of both graft types is growing.^{2,4,7,13,20,26} However, no comprehensive review of the evidence presented in these studies has been added to the orthopaedic literature. The purpose of this review is to systematically report on the outcomes of UCLR using the palmaris and hamstring tendons and determine whether one graft is associated with superior outcomes, with a particular focus on the RTS and return-to-same-level (RSL) rates. We hypothesized that there would be no difference in the RTS or RSL rates between UCLR performed with palmaris versus hamstring graft.

METHODS

Search Strategy

This systematic review of the current literature was performed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

TABLE 1
Eligibility Criteria^a

Inclusion Criteria	Exclusion Criteria
<ul style="list-style-type: none"> • Primary UCLR of elbow • Use of the palmaris longus or hamstring tendon grafts • Included RTS, failure rates, or PROs as outcomes • Controlled trials (randomized and unrandomized) • Prospective cohort studies • Retrospective cohort studies • Minimum 2-year follow-up 	<ul style="list-style-type: none"> • UCLR of thumb • Non-English language • No reported outcomes • Nonhuman studies • Basic science investigations • Review articles • Expert opinions • Technique reports • Revision UCLR • Allografts

^aPRO, patient-reported outcome; RTS, return to sport; UCLR, ulnar collateral ligament reconstruction.

guidelines. An electronic search of the literature was performed in April 2020 utilizing the PubMed, Embase, and Cochrane Library databases. Example search terms included "UCL," "ulnar collateral ligament," "medial collateral ligament," "valgus instability," "medial instability," "Tommy John surgery," "gracilis," "semitendinosus," "hamstring," "palmaris," and "palmaris longus." Search terms were combined in various permutations and combinations using Boolean operators to maximize the identification of relevant studies. The reference lists of included studies were also screened to identify additional related studies.

Eligibility Criteria

All studies reporting the outcomes of UCLR of the elbow with either hamstring or palmaris tendon autograft and at least 2 years of follow-up were included for screening. Only comparative studies including both graft options were included, and investigations on revision UCLR or allografts were excluded. All studies had to include at least 1 of the following outcome measures: RTS, RSL, reoperation/failure rates, or patient-reported outcomes (PROs). The inclusion and exclusion criteria are provided in Table 1. If eligible studies had overlapping patient samples, only the study with the largest sample size was included. Article screening was performed using the Covidence web platform (Veritas Health Innovation), which allowed for identification and removal of duplicate studies.

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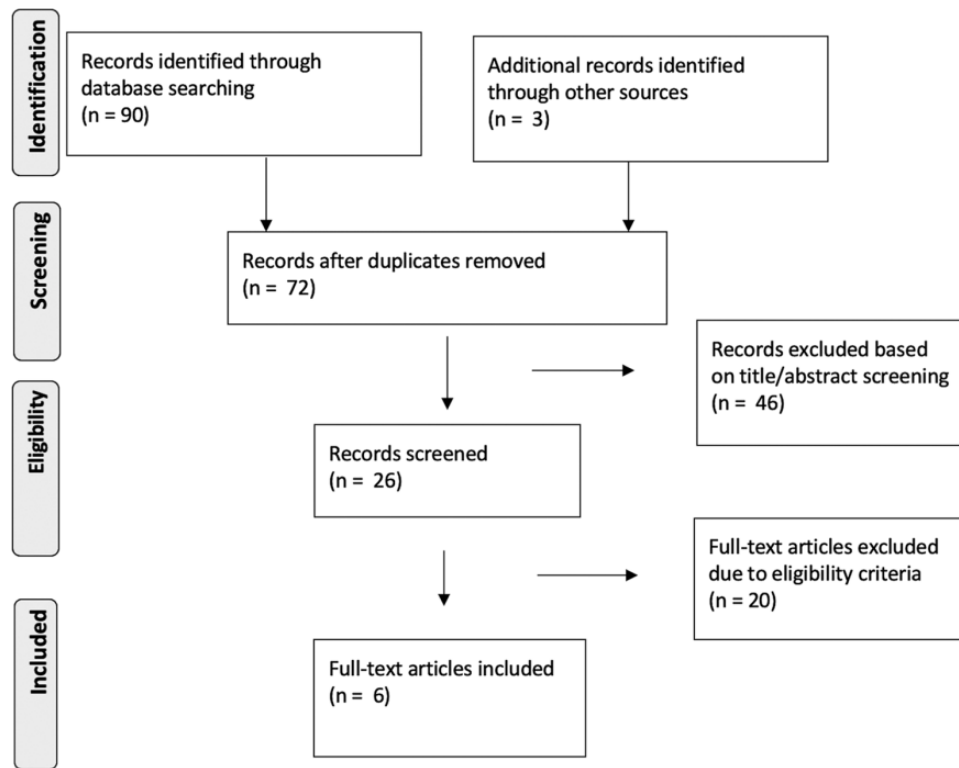


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the study selection process.

Data Collection

The following data were extracted by 2 authors (M.C. and C.R.C.): study characteristics (year, authors, institution, journal, study design, surgical technique, and number of each graft); patient demographics (age, sex, number of elbows, handedness, sport played, and level of sport); mean follow-up; concomitant procedures; complications; and failures. The following outcome measures were collected as available: RSL, RTS, and postoperative Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow Questionnaire; the Timmerman-Andrews score; and the Conway-Jobe scale.

Quality Assessment

The modified Coleman Methodology Score (mCMS) was used to assess the quality of included studies. Scoring was completed by 2 authors (M.C. and C.R.C.), with discrepancies resolved by discussion to achieve inter-reviewer agreement. Risk of bias for included studies was evaluated using a modified version²⁴ of the Cochrane Collaboration risk-of-bias tool for nonrandomized studies, and the risk of publication bias was assessed with a funnel plot.

Statistical Analysis

Microsoft Excel Version 16.37 (Microsoft) was used to generate all descriptive statistics, and correlation coefficients

were calculated to detect any correlations between mean age and both RSL and RTS. Review Manager Version 5.4.1 (Cochrane Collaboration) was used for meta-analysis, with application of a fixed-effects model to determine whether a significant difference in RSL rates existed between graft types. Heterogeneity was assessed via the chi-square test and I^2 statistic.

RESULTS

Search Results

A total of 90 records were identified as the result of searching the 3 electronic databases relevant to this investigation. Three additional records were identified after reviewing reference lists. After the removal of 21 duplicates, 72 articles remained. Of these, 46 articles were excluded after title and abstract screening, and another 18 were excluded after full-text review. Ultimately, after applying all eligibility criteria, 87 articles were excluded, and 6 articles were included for analysis (Figure 1).

Study Characteristics

The 6 studies included in this review were published between 2010 and 2019; all studies utilized both hamstring and palmaris grafts for reconstructions and stratified at least 1 surgical outcome based on graft type. All six studies

TABLE 2
Study Characteristics^a

Lead Author (Year)	Enrollment/ Follow-up, LOE	Follow-up, <i>n</i>	Mean Age, y	Follow-Up, months	Level of Play, %				Technique Used, %			Graft Type, %		
					Pro	Collegiate	HS	Rec	Modified Jobe	Docking	Other	Palmaris	Hamstring	Other
Arner (2019) ²	3	51/51	19.6	80.4	5.88	76.47	17.65	0	49.02	50.98	0	70.59	29.41	0
Cain (2010) ⁴	4	1281/743	21.5	37	NA	NA	NA	NA	100	0	0	74.29	23.55	2.15
Erickson (2016) ¹⁰	3	85/85	19.3	60	0	49.41	41.18	9.41	0	57.65	42.35	63.53	23.53	12.94
Griffith (2019) ¹³	3	566/566	23.5	≥24 ^b	100	0	0	0	51.24	30.21	18.55	63.78	23.85	12.37
Marshall (2019) ²⁰	2	46/46	26.3	36	100	0	0	0	60.87	36.96	2.17	76.09	23.91	0
Saper (2018) ²⁶	4	140/140	18	57.9	2.14	37.14	60	0.71	100	0	0	77.14	21.43	1.43

^aHS, high school; LOE, level of evidence; NA, not available. Pro, professional; Rec, recreational

^bGriffith et al¹³ did not specify mean follow-up.

TABLE 3
Modified Coleman Methodology Score

Study	Item (Possible Points) ^a											Total (100)
	No. 1 (10)	No. 2 (5)	No. 3 (5)	No. 4 (10)	No. 5 (15)	No. 6 (5)	No. 7 (5)	No. 8 (5)	No. 9 (10)	No. 10 (15)	No. 11 (15)	
Arner et al ²	4	5	5	10	10	5	5	5	10	11	10	80
Cain et al ⁴	10	3	0	10	0	5	3	5	10	3	10	59
Erickson et al ¹⁰	7	3	5	10	0	5	5	5	10	6	10	66
Griffith et al ¹³	10	0	5	10	0	5	3	0	10	3	10	56
Marshall et al ²⁰	4	3	5	10	0	5	3	0	10	3	10	53
Saper et al ²⁶	10	3	5	10	0	5	3	5	10	3	10	64
Mean ± SD	7.5 ± 2.95	2.83 ± 1.6	4.17 ± 2.04	10 ± 0	1.67 ± 4.1	5 ± 0	3.67 ± 1.03	3.33 ± 2.58	10 ± 0	4.83 ± 3.25	10 ± 0	63 ± 9.63

^aItem descriptions: 1 = study size; 2 = mean follow-up; 3 = percentage of patients with follow-up; 4 = number of interventions per group; 5 = study type; 6 = diagnostic certainty; 7 = description of surgical technique; 8 = description of postoperative rehabilitation; 9 = outcome criteria; 10 = procedure for assessing outcomes; 11 = description of participant selection process.

were retrospectively designed. The average follow-up ranged from 24 to 80.4 months. The investigation by Cain et al⁴ failed to collect final outcomes from all patients: 743 of the total 1281 patients were contacted for follow-up and included in their final analysis. A summary of study characteristics is listed in Table 2.

Patient Characteristics

A total of 2154 UCL reconstructions were included in this study, with a mean patient age of 21.8 years (range, 18.0-26.3 years). Excluding the study by Saper et al,²⁶ which did not report sex, 98.02% of patients were male. A total of 77.7% patients were right-handed, excluding the study by Cain et al,⁴ which did not report patient handedness. A total of 1529 elbows were included in the palmaris autograft group, and 505 elbows were included in the hamstring autograft group. The majority (96.7%) of the procedures were performed on baseball players, and the remaining athletes participated in javelin, football, and softball.

Quality of Included Studies

The overall mean mCMS was 63 ± 9.63. Although the mean score for study type was poor (1.67 ± 4.08), scores for percentage of patients with follow-up (4.17 ± 2.04), number of

interventions per group (10 ± 0.0), diagnostic certainty (5 ± 0.0), and outcome criteria (10 ± 0) were excellent (Table 3).

The risk-of-bias assessment showed that there was high risk of selection bias, given the nonrandomized design of all included studies. However, most other domains showed unclear or low risk of bias; for example, there was low risk of selective reporting of RSL or RTS, as these outcomes were prespecified in the study's methods. The complete risk-of-bias assessment is shown in Figure 2. Furthermore, we found no indication of publication bias across the 4 studies reporting RSL, which is shown in Figure 3.

Concomitant Procedures

Of the 6 included studies, 4 reported on additional procedures performed to address concomitant pathologies. Subcutaneous ulnar nerve transposition was the most commonly reported procedure, performed in 1622 (78.9%) cases, followed by the removal of a posteromedial olecranon osteophyte, performed in 398 (19.4%). The studies by Erickson et al¹⁰ and Griffith et al¹³ were the only 2 that compared UCLR with and without ulnar nerve transposition, and both showed that this concomitant procedure had no effect on the outcomes measured. In addition, Cain et al⁴ found no difference in the outcomes of patients with and without osteophyte excision. Concomitant procedures were not

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Risk of bias from confounding	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Arner et al [2]	+	+	+	?	?	+	?
Cain et al [4]	+	+	?	?	?	+	?
Erickson et al [10]	+	+	+	?	?	+	?
Griffith et al [13]	+	+	?	+	+	+	?
Marshall et al [20]	+	+	?	+	+	+	?
Saper et al [26]	+	+	?	?	?	+	?

Figure 2. Modified risk-of-bias assessment.

described in the studies by Marshall et al²⁰ and Arner et al.² A complete list of concomitant procedures and their frequencies can be found in Table 4.

Patient-Reported Outcomes

Postoperative KJOC scores were reported by authors in 3 studies,^{2,7,26} whereas Timmerman-Andrews Scores^{7,26} and the Conway-Jobe Score^{2,26} were each reported by authors of 2 studies. Arner et al² reported a significant difference in KJOC scores between the palmaris and hamstring graft groups, though Erickson et al¹⁰ and Saper et al²⁶ failed to find a significant difference. The studies that reported Timmerman-Andrews Scores^{7,26} and the Conway-Jobe scores^{2,26} also found no significant differences between graft groups. A summary of PROs is presented in Table 5.

Complications and Failures

Excluding Marshall et al,²⁰ who did not report complications or failures, 1585 patients were available for evaluation of complications and failures. The mean complication rate of the included studies was 18.2%. Cain et al⁴ reported the highest complication rate at 27.5%; however, 121 of these were minor ulnar neurapraxia and most cases

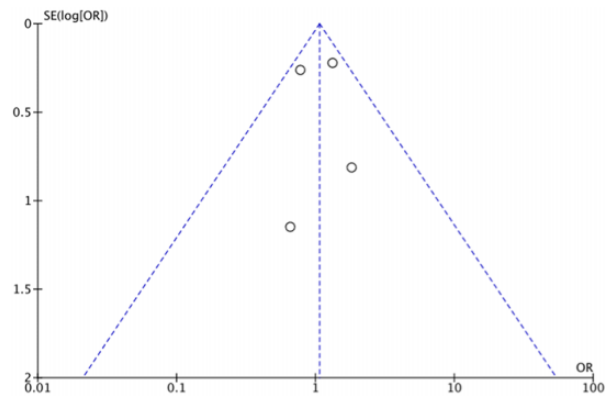


Figure 3. Funnel-plot analysis of publication bias for return to same level outcomes from 4 studies. OR, odds ratio.

resolved within 6 weeks. The lowest rate of complications, achieved by Saper et al,²⁶ was 3.6%. The highest rate of failure was reported by Erickson et al¹⁰ at 7.1%. Griffith et al¹³ reported the second highest rate of revision UCLR (4.2%), noting there was no significant difference between the revision rates in the palmaris and hamstring groups. Only 1 study² reported a 0% failure rate. A complete summary of complications and failure rates is presented in Table 6.

Return to Sport

Overall Results. The mean RSL across the 6 studies was 79.01% (range, 55%-93.24%). Notably, the study reporting the lowest RSL rate² also boasted the longest average follow-up at 80.4 months. The mean RTS across the 6 studies reporting was 84.1% (range, 79.9%-97.8%). A summary of overall RTS and RSL rates can be found in Table 7. Linear regression models showed only a small, nonsignificant association between age and both RTS ($r = -0.042$; $P = .938$) and RSL ($r = -0.116$; $P = .824$).

Results by Graft Type. The RSL rate for palmaris grafts was reported in 4 studies, inclusive of 1002 palmaris grafts, with a mean RSL rate of 81.96% (range, 75.40%-92.59%); the mean RSL rate for hamstring grafts was 80.76% (range, 69.9%-95.0%) across the 4 studies reporting, which comprised 341 grafts. None of the 4 studies observed a significant difference in the RSL rates between the palmaris and hamstring groups. RTS rates stratified by graft type were available in 2 studies, with a total of 396 palmaris grafts and 146 hamstring grafts. The mean RTS rate was 84.59% (83.1%-100%) for the palmaris group and 80.8% (80.7%-82.0%) for the hamstring group. Although Marshall et al²⁰ reported a significant difference in RTS rates between graft groups favoring palmaris grafts ($P = .01$), the larger study population analyzed by Griffith et al¹³ showed no such difference ($P = .596$). A complete list of RTS and RSL rates stratified by graft type for each study is presented in Table 8.

Meta-analysis. Meta-analysis was performed on the 4 studies reporting RSL rates; no statistical heterogeneity

TABLE 4
Concomitant Procedures

Concomitant Procedure	Frequency, % (n/N)	Studies Reporting
Subcutaneous ulnar nerve transposition	78.9 (1622/2057)	Cain et al, ⁴ Erickson et al, ¹⁰ Griffith et al ¹³
Excision of a posteromedial olecranon osteophyte	19.4 (398/2057)	Cain et al, ⁴ Griffith et al, ¹³ Saper et al ²⁶
Loose body removal	3.99 (82/2057)	Cain et al, ⁴ Griffith et al, ¹³ Saper et al ²⁶
Ulnar nerve in situ decompression	2.97 (61/2057)	Griffith et al ¹³
Flexor pronator debridement	1.26 (26/2057)	Cain et al, ⁴ Griffith et al ¹³
Submuscular ulnar nerve transposition	1.07 (22/2057)	Griffith et al ¹³
Excision of calcifications/ossicles	1.07 (22/2057)	Griffith et al, ¹³ Saper et al ²⁶
Radiocapitellar chondroplasty	0.53 (11/2057)	Griffith et al ¹³
Platelet-rich plasma injection	0.34 (7/2057)	Griffith et al ¹³
Screw fixation of an olecranon stress fracture	0.19 (4/2057)	Cain et al ⁴
Bone marrow aspirate concentrate injection	0.15 (3/2057)	Griffith et al ¹³
Lateral collateral ligament repair	0.15 (3/2057)	Cain et al ⁴
Capsular release	0.10 (2/2057)	Cain et al ⁴
Other	0.44 (9/2057)	Saper et al ²⁶

TABLE 5
Patient-Reported Outcomes by Study^a

PRO and Study	Elbows Evaluated	Palmaris Group Score	Hamstring Group Score	P
KJOC				
Arner et al ²	51	82.3 ± 20	57.9 ± 21.2	.001
Erickson et al ¹⁰	85	90.39 ± 7.06	89.62 ± 9.12	.251
Saper et al ²⁶	140	NR	NR	>.05
Timmerman-Andrews				
Erickson et al ¹⁰	85	91.67 ± 8.59	93.75 ± 5.82	.181
Saper et al ²⁶	140	NR	NR	>.05
Conway-Jobe				
Arner et al ²	51	NR	NR	.49
Saper et al ²⁶	140	NR	NR	>.05

^aKJOC, Kerlan-Jobe Orthopaedic Clinic; NR, not reported (study analyzed PROs but did not provide scores for individual graft types); PRO, patient-reported outcome. Bold *P* value indicates statistically significant difference between the palmaris and hamstring groups ($P < .05$).

was found among the studies ($I^2 = 0\%$; $P = .39$). Overall, meta-analysis showed no significant difference between the palmaris and hamstring graft groups with respect to RSL rates (odds ratio = 1.06; 95% CI, 0.77-1.46) (Figure 4).

DISCUSSION

The current gold standard of treatment for overhead athletes with a symptomatic, deficient UCL who have failed nonoperative treatment and wish to RTS at a high level is a UCLR. This procedure can be performed through a variety of techniques, utilizing a number of different grafts. Advances in these surgical techniques have produced excellent results, with greater than 80% of overhead athletes commonly able to RTS at a high level.^{12,31} Although the palmaris longus and hamstring tendons are the most commonly reported graft choices used to reconstruct the UCL of

the elbow, no comparison of the surgical outcomes between these graft types currently exists.

The purpose of this review was to systematically assess whether use of the palmaris or hamstring tendon autograft in UCL reconstruction significantly affected surgical outcomes. Our analysis revealed no significant difference in RSL rates between the 2 graft choices. The results from this study did find that younger age at the time of surgery was correlated with improved outcomes, but this correlation did not reach statistical significance. In addition, the overall RTS and RSL rates reported in our results are similar to those reported previously in the literature.

Dr Frank Jobe's original approach to UCL reconstruction, which involved detachment of the flexor-pronator muscles from their humeral attachment and passage of the palmaris longus tendon through 2 bone tunnels in a figure-of-8 configuration, resulted in RTS rates of 63%.¹⁵ Over the following decades, innovations in the approach to the flexor-pronator mass and to bone tunnel drilling provided new approaches that allowed RTS rates to reach 80%-90%.^{8,11,12,17,19} Our study found a pooled RTS rate of 84%, which is consistent with those previously reported in the literature.^{8,11,12,17,19} This study also reported a pooled RSL rate of 79.01%, which is in accordance with previous work. Azar et al³ reported an RSL rate of 81% in their cohort of 59 patients undergoing UCLR. Similarly, a 2014 systematic review by Watson et al³² that included 1080 patients reported an RSL rate of 78.9%.

This study represents the first systematic review comparing surgical outcomes between UCLRs using the palmaris and hamstring tendon grafts. With respect to graft type, our study found no significant difference in RSL between the palmaris and hamstring graft groups. In addition, only 1 study reported a significant difference in any PRO; Arner et al² found KJOC scores to be significantly higher for their palmaris cohort, although those authors postulated that this may have been the result of confounding variables or an inadequate number of hamstring autografts. The literature at large is conflicted about whether harvesting of hamstring autograft leads to persistent deficits in an athlete's kinetic

TABLE 6
Complication and Failure Rates^a

Study	Grafts Used	Complications	Failures
Arner et al ²	Palmaris, hamstring	<ul style="list-style-type: none"> • 3 transient ulnar nerve irritation (5.9%) • 3 medial epicondyle soreness (5.9%) • 4 (8%) future elbow surgeries (not revision UCLR) 	0% failure
Cain et al ^{4b}	Palmaris, hamstring	<ul style="list-style-type: none"> • 121 minor ulnar nerve neurapraxia (16.29%) • 27 graft-site complications (3.63%; most commonly superficial infection) • 53 reoperations for arthroscopic debridement of olecranon osteophyte (7.1%) 	9 revisions (1.2%)
Erickson et al ¹⁰	Palmaris, hamstring (gracilis)	8 (9.4%; 6 palmaris [11.1%] and 2 gracilis [10%])	6 reoperations (7.1%; 4 palmaris [7.4%] and 2 gracilis [10%])
Griffith et al ¹³	Palmaris, hamstring (gracilis)	65 subsequent elbow surgeries (11.5%; 46 palmaris [12.7%] and 19 gracilis [14.1%])	24 revisions (4.2%; 15 palmaris [4.2%] and 9 gracilis [6.7%])
Marshall et al ²⁰	Palmaris, hamstring	NR	NR
Saper et al ²⁶	Palmaris, hamstring	<ul style="list-style-type: none"> • 1 intraoperative ulnar nerve injury (0.7%) • 1 heterotopic ossification and arthrofibrosis requiring surgery within 12 mo (0.7%) • 1 excision of a calcium deposit within 12 mo (0.7%) • 2 medial epicondyle avulsion fractures (1.4%) 	NR

^aNR, not reported; UCLR, ulnar collateral ligament reconstruction.

^bOutcomes reported from 743 patients.

TABLE 7
Overall RTS and RSL Rates^a

Study	RTS		RSL	
	n/N (%) of Patients	Mean Time (mo)	n/N (%) of Patients	Mean Time (mo)
Arner et al ²	42/51 (83)	NR	28/51 (55)	NR
Cain et al ^{4b}	NR	NR	610/735 (83)	11.6
Erickson et al ¹⁰	NR	NR	69/74 (93.24)	NR
Griffith et al ¹³	452/566 (79.9)	14.5	403/566 (71.2)	17.3
Marshall et al ²⁰	43/45 (96)	13.7	36/44 (82)	NR
Saper et al ²⁶	135/138 (97.8)	11.6	124/138 (89.9)	NR

^aNR, not reported; RSL, return to same level; RTS, return to sport.

^bOutcomes reported from 743 patients.

chain.^{9,22} In a systematic review including over 400 reconstructions of the anterior collateral ligament of the knee using hamstring autograft, Papalia et al²² showed impairments in the volume and cross-sectional area of the hamstring muscle as well as decreases in deep knee flexion. However, these impairments were inversely correlated with average follow-up, suggesting time dependence and eventual improvement of deficits.²² A more recent study by Erickson et al⁹ compared the outcomes of UCLR using hamstring autograft from the driving leg versus the landing leg and found no difference in RTS rates, subsequent hamstring injury, or overall subsequent injury rates. The majority of the UCLRs in this review promoted the clinical efficacy of both graft types, and prior biomechanical investigations demonstrating their physical similarities corroborate this

result.²³ Overall, these findings suggest that the palmaris longus and hamstring tendons are viable graft options for athletes hoping to return to their sport.

Limitations

The majority of included studies were retrospective by design, with only 1 study prospectively collecting data. In addition, few studies directly comparing graft types were available in the literature; our review was only able to identify 6 such articles. The addition of further comparative studies to the literature would provide more power to detect significant differences in the outcomes between graft types. Data collection in each study was reliant on accurate documentation in patient medical records, and collecting outcome information from patients through telephone and follow-up visits presents the possibility of recall bias. Although RTS and RSL rates were reported by the most studies, there was inconsistent reporting of additional measures such as subsequent complications, concomitant procedures, and PROs. The consistent inclusion of these metrics would have allowed more rigorous investigation of the quality of a player's return to competition. Furthermore, although the docking and modified Jobe techniques were almost exclusively utilized for all included UCLRs, a wide range of concomitant procedures was performed across the studies; this heterogeneity must be taken into account when comparing outcomes across studies. Another consideration is that our study exclusively examined the use of autograft in UCLR; a growing body of literature is showing allografts to be comparable autografts for UCLR, particularly in nonelite athletes and laborers.^{18,27} Future directions should also evaluate the role of graft choice in outcomes after revision UCLR, as the rate of this

TABLE 8
RTS and RSL Rates by Graft Type^a

Study	Grafts Used		% RTS		P	% RSL		P
	Palmaris	Hamstring	Palmaris	Hamstring		Palmaris	Hamstring	
Arner et al ²	36	15	NR	NR	NR	NR	NR	NR
Cain et al ^{4b}	552	175	NR	NR	NR	85.14	88	.3
Erickson et al ¹⁰	54	20	NR	NR	NR	92.59	95	.999
Griffith et al ¹³	361	135	83.1	80.7	.596	75.4	69.9	.208
Marshall et al ²⁰	35	11	100	82	.01	83	73	.46
Saper et al ²⁶	108	30	NR	NR	NR	NR	NR	NR

^aNR, not reported; RSL, return to same level; RTS, return to sport.

^bOutcomes reported from 743 patients.

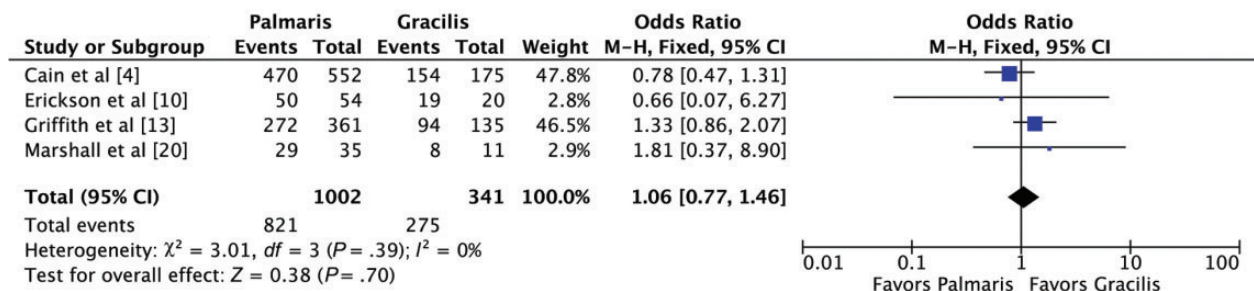


Figure 4. Meta-analysis comparing rates of return to same level between the palmaris and gracilis (hamstring) graft groups. M-H, Mantel-Haenszel.

procedure has increased nearly 10-fold over the past few decades and presents new considerations regarding graft selection.

CONCLUSION

This study found no difference in RSL rates between the palmaris and hamstring graft cohorts. Furthermore, RTS and RSL rates for this study's pooled patient population were similar to those previously reported in the literature. These results support both the palmaris and the hamstring tendons as safe and effective options for primary UCLR. An individualized approach that considers both surgeon and patient preference should be employed to determine the optimal graft choice for each case.

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