Systematic Review

Primary Repair, Reconstruction, and Suture Tape Augmentation All Provide Excellent Outcomes for Lateral Ligament Instability: A Systematic Review

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Purpose: To analyze the literature to compare outcomes and complications following primary lateral ankle ligament repair compared with lateral ankle ligament reconstruction and the suture tape augmentation in patients with lateral ankle instability. **Methods:** Following the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) criteria, a systematic literature review using the PubMed/Ovid Medline database was performed (October 11, 1947, to October 1, 2019). Clinical trials that included all the following criteria were considered eligible; published in the English language; patients undergoing primary lateral ankle repair or reconstruction with/without autograft or allograft (anterior talofibular ligament, anterior talofibular ligament + calcaneofibular ligament) or suture tape augmentation; a follow-up at least 1 year; reported least 1 of the measured outcomes (The American Orthopaedic Foot Ankle Score, Karlsson Score, return to sport [RTS], complications, skin wound complications, reoperation). Surgical techniques were evaluated, and studies were subdivided by the following categories: primary repair (PR), reconstruction with graft (GR), and suture tape augmentation (STA). Complications, radiographic outcomes, functional outcome scores, and RTS were analyzed. **Results:** A total of 41 of 1,991 studies met the criteria for final analysis. This included 1,920 patients who underwent surgical intervention for chronic lateral instability with at least a 1-year follow-up. There were 350 patients who had GR, 1,486 who underwent the PR, and 84 who had STA. GR group appeared to have the lowest rate of complications: GR 3.1% (11 of 350), PR 4.2% (63 of 1486), and STA 10.7% (9 of 84). Postoperative American Orthopaedic Foot Ankle Score ranged from 89.0 to 95.1 for GR and 90.0 to 98.8 for PR. Postoperative Karlsson scores ranged from 80.9 to 94.4 for GR and from 89.2 to 94.1 for PR. Anterior drawer postoperative scores ranged from 1.4 to 30.3 mm for GR, 2.7 to 8.6 mm for PR, and 4.1 to 4.2 mm for STA. Postoperative talar tilt ranged from 2.4 to 7.3° for GR, 1.9 to 6.0° for PR, and 3.6 to 4.5° for STA. RTS ranged from 9.5 to 20.4 weeks for the PR group; one study reported a RTS of 10.6 weeks for STA. **Conclusions:** Excellent outcomes were noted across all intervention groups. Current literature may suggest there is no difference in functional outcomes between patients treated with PR versus GR. However, there may be a potential improvement in functional outcomes with PR versus STA. **Level of Evidence:** Level IV, systematic review of Level I to Level IV studies.

Ankle injuries make up about 40% of all sports and recreational activity injuries, especially in sports such as basketball, soccer, cross-country running, and more.[1] Typically, these ankle injuries are associated with a ligament rupture, primarily the anterior talofibular ligament (ATFL) and calcaneofibular ligament.[2] Most of these ankle injuries can be treated effectively with conservative methods; however, some patients will not respond to conservative treatment and continue to have chronic symptoms or chronic lateral

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ankle instability (CLAI).[3] These chronic symptoms can be severely disabling, especially in patients with high use of ankle joint function, such as athletes.[4] After nonresponse to conservative treatment, surgical repair of these injuries is indicated.[3] The use of the Broström technique has increased for the surgical repair of these injuries, showing excellent outcomes and becoming the gold standard in treating CLAI when operative intervention is required.[5]

However, there are multiple techniques used for the surgical treatment of CLAI. These techniques include anatomic direct repair with or without local tissue augmentation, anatomic ligament reconstruction using either an autograft or an allograft, and arthroscopic repair.[6] Anatomic direct repair uses native ligament remnants with or without local tissue for added support whereas anatomic ligament reconstruction is used when the patient has poor ligament remnants.[6] Autograft ligament reconstruction has superior tissue quality but runs the risk of donor-site morbidity and increased postoperative pain whereas allograft ligament reconstruction avoids these risks but does not have the quality of tissue from an autograft.[6] Arthroscopic repair is performed using mainly suture anchors with the idea that this procedure reduces postoperative pain and complications while also speeding up recovery.[6] Ligament repair augmentation using suture-tape is a new novel technique for CLAI.[7] This procedure theoretically reduces the likelihood of needing an anatomic ligament reconstruction.[7] Recent biomechanical studies have shown good success of an augmented ATFL reconstruction using suture tape, but more clinical evidence is needed.[7]

There is little agreement on what surgical procedure should be used on patients with CLAI demonstrated by the many different techniques that have been described. More research is needed about the benefits of each technique to better assess which technique is right for each individual patient. The purpose of this review is to analyze the literature to compare outcomes and complications following primary lateral ankle ligament repair compared with lateral ankle ligament reconstruction and the suture tape augmentation in patients with lateral ankle instability. The hypothesis of this study is that results from primary lateral ankle ligament repair versus lateral ankle ligament reconstruction and suture tape augmentation would have differing outcomes.

Methods

Search Strategy and Study Selection

This study followed the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines. Since this study was a systematic review of published studies, institutional review board approval was not required. A systematic literature review performed on November 1, 2019, was conducted using the PubMed/Ovid/MEDLINE database; dates of publication was limited to October 11, 1947, through October 1, 2019. The main key words "lateral ankle repair; Lateral ankle ligament repair; Lateral ankle ligament reconstruction; Broström; Broström-Gould; Broström Gould; Modified Broström" were used in the electronic search. Two investigators performed a separate, manual study selection from this list to exclude repetitions and to select those specifically related to discussed item. In case of any discrepancies in article selection between the 2 investigators, a third investigator was involved. Only studies published in the English language were included in this study. The reference list of each selected article also was screened for additional articles that met the inclusion criteria. Due to a lack of high-level evidence looking at the comparison between these surgical techniques, nonrandomized trials were included. We felt it was more valuable to include all literature on these surgical techniques and their outcomes.

Eligibility Criteria

Clinical trials that included all the following criteria were considered eligible; published in the English language; patients undergoing primary lateral ankle repair or reconstruction with/without autograft or allograft (ATFL, ATFL + calcaneofibular ligament) or suture tape augmentation; a follow-up at least 1 year; reported least one of the measured outcomes (The American Orthopaedic Foot Ankle Score [AOFAS], Karlsson Score, return to sport [RTS], complications, skin wound complications, reoperation). Studies were excluded if they included patients with any of the following: those who underwent revision ligament repair, reconstruction, or suture tape augmentation; who had concomitant talar chondral or osteochondral repair or reconstructive procedures; who had concomitant peroneal tendon procedures (peroneal tendon debridement, tendon repair); who underwent concomitant superior peroneal retinaculum repair; had concomitant treatment of hindfoot or forefoot pathology (calcaneal osteotomy for cavovarus reconstruction, subtalar arthrodesis); and/or who had a syndesmosis repair or ankle fracture open reduction and internal fixation.

Data Extraction and Quality Appraisal

Operative techniques for each study were reviewed and divided into 3 categories; primary repair group (PR), graft reconstruction group (GR), and suture tape augmentation group (STA). Patients treated with the modified Broström technique were included in the PR group.[8] The GR group was further subdivided into autograft or allograft. STA was defined as using additional suture tape fixation that was anchored to both

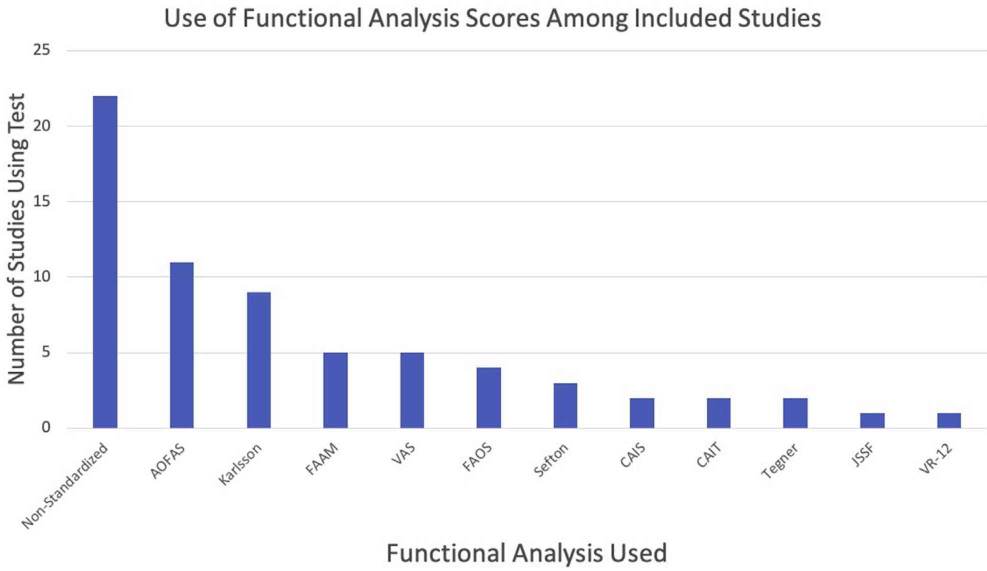

Fig 1. The wide variety and inconsistency with which functional outcomes were measured across all the used studies is shown.

the fibula and talus. RTS, talar tilt, anterior drawer, functional outcome scores (AOFAS, Karlsson score), and total complications of 3 populations were recorded and compared. Skin wounds were then subdivided out of the total complications and were defined as either having one of the following: wound dehiscence, wound

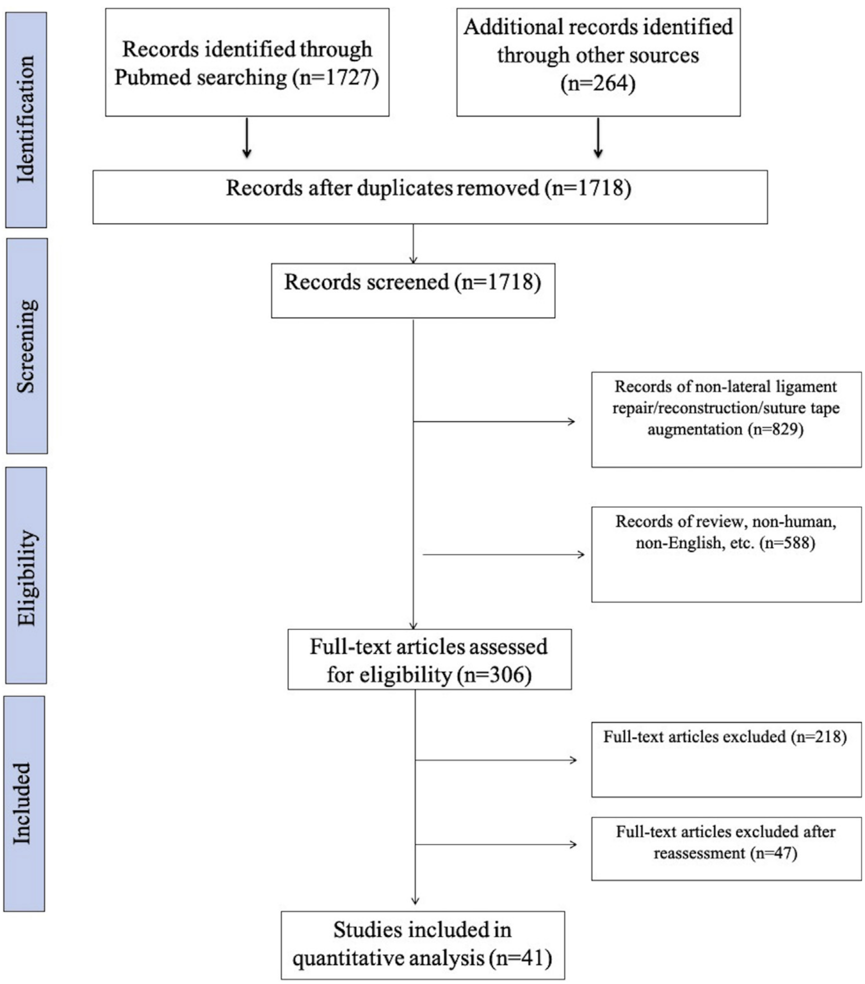

Fig 2. Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) flowchart for article selection.

Table 1. Studies by Operative Technique

Author	Year	Graft Reconstruction	Primary Repair	Suture Tape Augmentation	Male	Female	Average Age, y (Range)	Range of Follow-Up (Months)	Level of Evidence
Graft reconstruction									
Giannini et al.[15]	2014	21			n/a	n/a	25.9 (n/a)	24-96	IV
Miyamoto et al.[16]	2014	33			23	10	27.1 (18-43)	24	III
Nakata et al.[17]	2000	20			n/a	n/a	20.2 (15-31)	37.2-120	IV
Park et al.[18]	2016	30			23	7	23.9 (17-54)	12-33	IV
Sammarco et al.[4]	1999	30			17	13	30.0 (12-47)	24-64	IV
Ventura et al.[22]	2018	20			12	8	29.2 (18-40)	180	III
Wang et al.[19]	2013	25			14	11	32.4 (17-62)	12-56	IV
Wang et al.[20]	2017	19			10	9	27.9 (19-41)	12-40	IV
Xu et al.[6]	2014	68			41	27	32.8 (n/a)	21.8-40.2	III
Youn et al.[21]	2012	14			9	5	29.1 (20-53)	12-40	IV
Total graft reconstruction	n=10	280			149	90			
Primary repair									
Agoropoulos et al.[24]	1997		75		60	15	n/a (15-53)	12-180	IV
Alghern et al.[25]	1989		76		50	26	28.0 (16-55)	12-70	IV
Brodsky et al.[5]	2005		73		29	44	31.0 (15-61)	14-120	IV
Buerer et al.[8]	2013		41		16	25	33.7 (18-60)	13-72	IV
Burn et al.[10]	2013		41		16	25	33.7 (18-60)	24-34	IV
Cho et al.[26,27] Transosseous suture	2012		20		12	8	33.9 (21-42)	24-33	I
Cho et al.[27] Suture anchor	2012		20		11	9	30.7 (15-44)	24-34	I
	2015		24		17	7	23.1 (17-28)	24-41	II
Evans et al.[28]	1984		50		39	11	24.7 (16-35)	24	III
Giannini et al.[13]	2014		17		n/a	n/a	25.9 (n/a)	24-96	IV
Gould et al.[29]	1980		50		34	16	n/a	12-n/a	IV
Hamilton et al.[30]	1993		27		14	13	28.1 (18-59)	30-132	IV
Iwao et al.[31]	2014		10		5	5	27.0 (16-30)	12-n/a	III
Jarvela et al.[32]	2002		32		20	12	27.0 (13-43)	2.1-4.0	III
Jaskulka et al.[33]	1988		268		135	133	25.9 (12-62)	24-72	IV
Jeong et al.[34]	2016		45		19	26	32.0 (17-75)	24-70.3	III
Karlsson et al.[35-38]	1988		148		93	55	23.0 (17-42)		IV
	1989		60		35	25	23.0 (18-39)	24-60	IV
	1995		40		22	18	24.0 (17-35)	24-n/a	IV
	1999		30		18	12	27.0 (18-36)	24-n/a	IV
Keller et al.[39]	1996		39		n/a	n/a	33.8 (n/a)	12-n/a	IV
Lofvenberg et al.[40]	1994		27		21	6	30.0 (16-54)	12-83	II
Matsui et al.[41]	2016		37		20	17	28.0 (8-59)	12	III
Messer et al.[42]	2000		22		10	12	27.2 (15-44)	18-72	IV
Petrera et al.[43]	2014		49		23	26	25.0 (18-37)	24-60	IV
Porter et al.[44]	2019		25		13	12	24 (16-41)	60	I
Russo et al.[45]	2016		18		11	7	21.5 (17-32)	120-180	IV
Saragaglia et al.[46]	1997		32		14	18	25.0 (16-44)	12-n/a	IV
Schmidt et al.[2]	2004		32		32	0	n/a	18-61	II
Trichine et al.[47]	2017		38		38	0	24.2 (19-31)	30-86.4	III
Ventura et al.[20]	2018		20		11	9	27.4 (18-40)	180	III
Xu et al.[6]	2019		28		n/a	n/a	28.1(17-55)	12-24	III
Total primary repair	n=31		1514		838	592			
Suture tape augmentation									
Cho et al.[49]	2015			34	0	34	26.2 (16-38)	24-39	IV
Cho et al.[48]	2015			28	19	9	29.5 (18-43)	24-52	IV
Porter et al.[44]	2019			22	12	10	26.1 (16-43)	60	I
Xu et al.[6]	2019			25	n/a	n/a	26.6(16-50)	12-24	III
Total suture tape augmentation	n=4			109	31	53			

n/a, not available.

*Sex was not reported for 150 (7.9%) cases.

Table 2. Participant Demographics by Operative Technique

	Sample Size		Male		Female		Average
Operative Technique	n = 1,920	100.0%	n = 1,078	56.1%	n = 755	39.3%	Age
Graft reconstruction	350	18.2	199	10.4	110	5.7	28.4
Athletes	54		23		10		26.4
General population	296		176		100		De
Primary repair	1486	77.4	838	43.6	592	30.8	26.9
Athletes	18		11		7		21.5
General population	1286		688		542		27.0
Unknown	182		139		43		24.0
Suture tape augmentation	84	4.4	41	2.1	53	2.8	30.6
General population	62		19		43		27.7
Unknown	22		42		61		32.3

*Sex was not reported for 97 (5.0%) cases.

drainage, and/or cellulitis. Reoperation rate also was evaluated for and analyzed between the 3 groups. The Karlsson score followed by the traditional scoring scale (0-100) that was first described Karlsson and Peterson.[9] The following parameters were evaluated for the Karlsson Score: pain, swelling instability, stiffness, stair climbing, running, working activities, and support.[9] The Karlsson score was interpreted as poor if <60, fair if 60 ≤ Karlsson ≤ 74, good if 75 ≤ Karlsson ≤ 84, and excellent if 85 ≤ Karlsson ≤ 100.[9] Similarly, AOFAS scoring scale (0-100) was also used.[10] The following parameters were also evaluated for AOFAS: pain, function, and alignment.[11] The AOFAS score was interpreted as poor if <50, fair if 50 ≤ AOFAS ≤ 74, good if 75 ≤ AOFAS ≤ 89, and excellent if 90 ≤ AOFAS ≤ 100.[11] A variety of functional outcome measurement tools were used in all the studies, as seen in Fig 1. However, the Karlsson and AOFAS scores were most commonly used. The GR group was further subdivided to autograft or allograft and the above variables also were analyzed between these 2 populations. Assessment of methodologic quality was conducted with the Cochrane Collaboration Tool[12] was performed by 2 reviewers (A.T. and M.H.; a third tiebreaker [M.V.] was designated in case of any disagreement).

Statistical Analysis

Statistical analysis was for the overall cohort of studies was conducted in IBM SPSS Statistics, version 26 (IBM Corp., Armonk, NY), with the criterion for alpha set at 0.05 as the level of significance. Data from each article were summarized by operative technique. Descriptive statistics was performed for each study, and parameters were analyzed. For each variable evaluated, the number and percentage of studies that reported the variable was calculated. Frequencies and percentages were reported for categorical variables; means and standard deviations were reported for continuous variables.

Meta-analyses were conducted in RStudio, using R version 4.0.1, following Harrer, Cuijpers, Furukawa, and Ebert 2019.[13] Mixed-effects models (random-effects within subgroups and fixed-effects between subgroups) were conducted. The meta-analytical method included the inverse variance method, Sidik—Jonkman estimator for tau,[2] Hartung—Knapp adjustment, and Hedges' g (bias corrected standardized mean difference). These methods were chosen because the number of studies were small and heterogeneity may be problematic. To determine the extent to which heterogeneity was present, the rule of thumb outlined in Higgins et al.[12] was used to indicate the percentage of variability in effect sizes not caused by sampling error, where $I^2 = 25\%$ is low, $I^2 = 50\%$ is moderate, and $I^2 = 75\%$ is substantial heterogeneity. For each model, pre- and postoperative measures were compared using the standardized mean difference (SMD). A total of 4 models were developed: 2 for the functional measure (AOFAS and Karlsson scores) and 2 for the radiographic measure (anterior drawer and talar tilt).

Results

The initial PubMed/Ovid MEDLINE database search identified 1,992 articles. Of those, 1,685 articles were excluded because they did not meet the inclusion criteria (Fig 2). Of the remaining 307 studies, 89 were selected for initial screening. In total, 48 articles were critically reassessed, and 41 articles remained after the secondary screen. Table 1 shows the studies included in the analysis by operative technique; 10 studies used GR,[4,6,13-21] with n = 280 participants; 31 studies in PR,[2,5,8,10,22-46] n = 1,514; and 4 studies reported STA[7,42,47] in their surgical fixation, n = 109; for a total of 1,903 participants.

Patient Demographics

The analysis included 1,018 males and 735 females; sex was not reported for 150 patients. The ages ranged from 20.2 to 33.9 years, with 157 unreported. Table 2 shows participant demographics by operative technique and by athletes versus general population. The majority of participants had a primary repair procedure, were male, and were categorized as general population.

	Selection method	Exposure ascertainment	Outcome Ascertainment	Alternative outcome explanation?	Challenge/rechallenge phenomenon?	Dose-response effect?	Follow up long enough?	Enough results to replicate/make inferences?	Total Score
Agoropoulos, Z et al[24]	✓	✓	X	X	X	X	✓	✓	4
Algherns et al[25]	✓	✓	✓	X	X	X	✓	✓	5
Brodsky et al[5]	✓	✓	✓	X	X	X	✓	✓	5
Buerer et al[8]	✓	✓	✓	X	X	X	✓	X	4
Burn et al[10]	✓	✓	X	X	X	X	X	✓	3
Cho et al[26]	X	X	✓	X	X	X	✓	✓	3
Cho et al[27]	✓	✓	✓	X	X	X	✓	✓	5
Cho et al[48]	✓	✓	✓	X	X	X	✓	✓	5
Cho et al[49]	X	X	✓	X	X	X	✓	✓	3
Evans et al[28]	✓	✓	X	X	X	X	✓	✓	4
Giannini et al[15]	✓	✓	✓	X	X	X	✓	✓	5
Gould et al[29]	X	X	X	X	X	X	X	✓	1
Hamilton et al[30]	X	✓	X	X	X	X	X	X	1
Iwao et al[31]	X	X	X	X	X	X	X	X	0
Jarvela et al[32]	✓	✓	✓	X	X	X	✓	✓	5
Jaskulka et al[33]	X	✓	✓	X	X	X	✓	✓	4
Jeong et al[34]	✓	✓	✓	X	X	X	✓	✓	5
Karlsson et al[35]	X	✓	X	X	X	X	✓	✓	2
Karlsson et al[36]	✓	✓	X	X	X	X	✓	✓	4
Karlsson et al[37]	X	✓	✓	X	X	X	✓	✓	4
Karlsson et al[38]	X	✓	✓	X	X	X	✓	✓	4
Keller et al[39]	X	✓	✓	X	X	X	✓	✓	4
Lofvenberg et al[40]	X	✓	✓	X	X	X	✓	✓	4
Matsui et al[41]	✓	✓	X	X	X	X	X	✓	3
Messer et al[42]	✓	✓	X	X	X	X	✓	✓	4
Miyamoto et al[16]	✓	✓	✓	X	X	X	✓	✓	5
Nakata et al[17]	✓	✓	✓	X	X	X	✓	✓	5
Park et al[18]	✓	✓	✓	X	X	X	✓	✓	5
Petrera et al[43]	✓	✓	✓	X	X	X	X	✓	4
Porter et al[44]	✓	✓	✓	X	X	X	✓	✓	5
Russo et al[45]	✓	✓	✓	X	X	X	✓	✓	5
Sammarco et al[4]	X	✓	✓	X	X	X	X	✓	3
Saragaglia et al[46]	✓	✓	X	X	X	X	✓	X	3
Schmidt et al[2]	X	X	✓	X	X	X	✓	✓	3
Trichine et al[47]	X	✓	✓	X	X	X	✓	✓	4
Ventura et al[23]	✓	✓	✓	X	X	X	✓	✓	5
Wang, B et al[19]	✓	✓	✓	X	X	X	✓	✓	5
Wang, W et al[20]	X	✓	✓	X	X	X	✓	✓	4
Xu et al[50]	✓	✓	✓	X	X	X	✓	✓	5
Xu et al[6]	X	✓	✓	X	X	X	✓	✓	4
Youn et al[21]	✓	✓	✓	X	X	X	✓	✓	5

Fig 3. The risk of bias present in each article used in the review.

Quality Bias Results

+	Low risk of bias
?	Unclear risk of bias
–	High risk of bias

		Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
		Primary Repair						
Agoropoulos et al[22]	1997	-	-	-	-	+	-	+
Algherns et al[23]	1989	-	-	-	+	+	+	+
Brodsky et al[5]	2005	-	-	-	+	+	+	+
Buerer et al[8]	2013	-	-	-	-	?	-	+
Burn et al[10]	2013	-	-	-	+	+	+	+
Cho et al[24]	2012	+	-	-	+	+	+	+
Cho et al[25]	2015	-	-	-	+	+	+	+
Evans et al[26]	1984	+	+	?	-	+	+	+
Gould et al[27]	1980	-	-	-	+	+	+	+
Hamilton et al[28]	1993	-	-	-	-	+	-	+
Iwao et al[29]	2014	-	-	-	-	-	-	+
Jarvela et al[30]	2002	+	-	+	+	+	+	+
Jaskulka et al[31]	1988	-	-	-	-	+	-	+
Jeong et al[32]	2016	-	-	-	+	+	+	+
Karlsson et al[3]	1988	-	-	-	-	+	-	+
Karlsson et al[34]	1989	-	-	-	-	+	-	+
Karlsson et al[35]	1995	-	-	-	-	+	+	+
Karlsson et al[36]	1999	-	-	-	+	+	+	+
Keller et al[37]	1996	-	-	-	-	+	-	+
Lofvenberg et al[38]	1994	-	-	-	-	-	-	+
Matsui et al[39]	2016	-	-	-	-	?	-	?
Messer et al[40]	2000	-	-	-	-	+	-	?
Petrera et al[41]	2014	-	-	-	-	+	-	?
Porter et al[42]	2019	+	-	-	-	+	-	+
Russo et al[43]	2016	-	-	-	-	+	-	+
Saragaglia et al[44]	1997	-	-	-	-	-	-	+
Schmidt et al[2]	2004	-	-	-	-	+	-	+
Trichine et al[45]	2017	-	-	-	-	+	-	+
Gould et al[27]	1980	+	-	-	+	+	+	+
		Suture Tape Augmentation						
Cho et al[46]	2015	-	-	-	+	+	+	+
Cho et al[47]	2017	-	-	-	-	+	-	+
Porter et al[42]	2019	+	-	-	-	+	-	+
		Graft Reconstruction						
Cho et al[46]	2015	-	-	-	-	-	-	+
Lee et al[20]	2017	-	-	-	-	-	+	+
Miyamoto et al[14]	2014	+	+	-	-	-	+	+
Nakata et al[15]	2000	-	-	-	-	+	+	+
Park et al[16]	2016	-	-	-	-	-	-	+
Sammarco et al[4]	1999	-	-	-	-	-	-	+
Ventura et al[21]	2018	-	-	-	-	-	+	+
Wang, B et al[17]	2013	-	-	-	-	-	-	+
Wang, W et al[18]	2017	-	-	-	-	-	-	+
Xu et al[6]	2014	-	-	-	-	-	-	+
Youn et al[19]	2012	+	+	-	-	-	-	+

Fig 4. The authors' quality of bias assessment used in the review.

Domains	Leading explanatory questions
Selection	1. Does the patient(s) represent(s) the whole experience of the investigator (center) or is the selection method unclear to the extent that other patients with similar presentation may not have been reported?
Ascertainment	2. Was the exposure adequately ascertained?
	3. Was the outcome adequately ascertained?
Causality	4. Were other alternative causes that may explain the observation ruled out?
	5. Was there a challenge/rechallenge phenomenon?
	6. Was there a dose–response effect?
Reporting	7. Was follow-up long enough for outcomes to occur?

Fig 5. Questions used in Figure 4 for our quality of bias assessment.

The age range was similar across operative techniques: for the GR group, it was 20.2 to 32.8 years; PR was 21.5 to 33.9; STA was 26.1 to 29.5 years.

Quality Bias Assessment

Risk of bias results can be found in Figure 3. Our literature review showed only 2 studies with level 1 evidence.[24,42] Further, only 8 studies randomized their patient cohorts.[14,19,24,26,30,36,42,45] Porter et al.[44] randomized their cohort and compared outcomes between PR and STA and demonstrated a low risk for bias. However, the majority of studies were case series. Thus, due to this high risk of bias, no formal meta-analysis was able to be performed.

To evaluate the quality of bias in the papers included in our study, the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach was used. The Quality of Bias assessment can be found in Figure 4. This approach uses 8 parameters to evaluate the quality of bias in case reports/series, and a score between 0 and 8 is given. It is tough to solely rely on the aggregate score to determine the quality of the study because some questions have more of an impact on the quality of the paper than others. Therefore, it is recommended that the reader determine which question(s) play a more important role for their research process and look at the value of said questions for the papers. Also, questions 4, 5, and 6 are mostly relevant to case series looking at adverse drug events, which is why all of the studies included here have a value of 0 for those questions. Each leading explanatory question is listed at the bottom of Figure 5.

Pre- and Postoperative Assessments

Functional Outcomes (AOFAS and Karlsson)

AOFAS were reported for 374 participants from 11 studies,[6,13,16-18,20,21,32,43,45] 183 in the GR group,[6,13,16-18,20,21] 166 in PR,[21,32,43,45] and 25 in the STA group[48] (Table 3). Postoperative AOFAS ranged from 89.0 to 95.1 for GR, 90.0 to 98.8 for PR, and 97.5 for STA. GR, PR, and STA saw improvements in their AOFAS scores. Postoperative−preoperative differences ranged from 24.0 to 34.6 for GR, from 20.1 to 38.0 for PR, and 29.3 for STA. Two studies[13,21] compared GR with PR; none found a significant difference between postoperative AOFAS scores. One study[6] compared PR with STA and did not find a significant difference in preoperative or postoperative AOFAS scores.

Karlsson scores were reported for 240 participants from 8 studies.[14,18-21,24,25,45] There were 118 participants from 5 studies in the GR group[14,16,18-21] and 122 participants from 4 studies in the PR group.[21,24,25,45] Postoperative scores ranged from 80.9 to 94.4 for GR and from 89.2 to 94.1 for PR. Both groups saw improvements: postoperative−preoperative differences ranged from 26.4 to 40.1 for GR and from 16.7 to 48.7 for PR. Ventura et al.[23] compared GR with PR and found no significant difference between the 2 groups in terms of Karlsson scores. Further, none of the analyzed studies reported Karlsson scores for the STA group.

Radiographic Outcomes (Anterior Drawer and Talar Tilt)

Anterior drawer measurements were reported in 21 studies for a total of 670 participants (Table 4). There were 163 patients in the GR group,[14-21] 420 patients in the PR group,[2,21,24,25,30,32,39,40,44,45,46,48] and 87 in the STA group.[7,47] Anterior drawer postoperative scores ranged from 1.4 to 7.2 mm for GR, 2.7 to 8.6 mm for PR, and 2.9 to 4.2 mm for STA. All groups saw improvements: preop−postoperative scores ranged from 2.9 to 7.7 mm for GR, 1.7 to 9.2 mm for PR, and 7.9 to 9.3 mm for STA. Ventura et al.[21] compared GR with PR and found the PR group to have increased stability, as measured by anterior drawer: 1.4 mm (0.9) for PR compared with 5.7 mm (1.1) for GR, $P < .01$. Xu et al.[6] compared PR with STA and found no significant difference in the 2 groups in the anterior drawer outcomes.

Talar tilt was measured in 21 studies[6,7,14-21,24,29,32,35,36,39,40,44-47] and were reported in 706 participants: 231 for 8 GR studies,[6,14-21] 388 for 12 PR studies,[2,21,24,32,35,36,39,40,44-46] and 87 for 3 STA studies.[7,47] Postoperative talar tilt values were as follows: 2.4-7.3° for GR, 1.9-6.0° for PR, and 2.4-4.5° for STA. Weighted mean differences, preoperative−postoperative, for each technique were

Table 3. Functional Outcomes Measured Pre- and Postsurgery, by Study

Author	Year	N	Graft Type	AOFAS Preoperative*	AOFAS Postoperative	AOFAS Difference	Karlsson Preoperative	Karlsson Postoperative	Karlsson Difference
Graft reconstruction									
Giannini et al.[15]	2014	21	Auto- plantar gracilis. Allo-peroneus brevis	n/a	92.5 (6.3)	n/a	n/a	n/a	n/a
Autograft									
Miyamoto et al.[16] (immobilized group)	2014	15	Gracilis	n/a	n/a	n/a	62.3 (4.7)	94.4 (7.1)	32.1
Miyamoto et al.[16] (accelerated group)	2014	20	Gracilis	n/a	n/a	n/a	64.1 (4.8)	91.7 (7.7)	27.6
Park et al.[18]	2016	30	Peroneus longus	57.2	89.0	31.8	66.9	93.3	26.4
Ventura et al.[23]	2018	20	Peroneus Brevis	60.2 (10.2)	90.1 (8.2)	29.9	59.8 (9.2)	92.1 (8.7)	32.3
Wang et al.[19]	2013	25	Semitendinosus	71.1	95.1	24.0	n/a	n/a	n/a
Xu et al.[6]	2014	32	Semitendinosus	62.3 (8.2)	95.1 (7.5)	32.8	n/a	n/a	n/a
Allograft									
Wang et al.[20]	2017	19	Semitendinosus	64.0	90.3	26.3	50.8	90.9	40.1
Xu et al.[6]	2014	36	Unspecified	60.2 (8.4)	94.8 (5.5)	34.6	n/a	n/a	n/a
Youn et al.[21]	2012	14	Semitendinosus	n/a	n/a	n/a	54.2	80.9	26.7
Primary repair									
Cho et al.[26] (suture anchor group)	2012	20		n/a	n/a	n/a	46.4 (7.96)	90.8 (6.15)	44.4
Cho et al.[26] (transosseous suture group)	2012	20		n/a	n/a	n/a	44.5 (7.19)	89.2 (6.44)	44.7
Cho et al.[27]	2015	24		n/a	n/a	n/a	43.5 (n/a)	92.2 (n/a)	48.7
Giannini et al.[15]	2014	17		n/a	91.8 (5.2)	n/a	n/a	n/a	n/a
Jeong et al.[34] (stress + group)	2016	35		65.1 (14.6)	90.0 (6.4)	24.9	n/a	n/a	n/a
Jeong et al.[34] (stress − group)	2016	10		72.5 (9.3)	92.6 (7.8)	20.1	n/a	n/a	n/a
Russo et al.[45]	2016	18		67.6 (n/a)	98.9 (n/a)	31.2	n/a	n/a	n/a
Trichine et al.[47]	2017	38		57.0 (n/a)	95.0 (n/a)	38.0	75.5 (n/a)	92.2 (n/a)	16.7
Ventura et al.[23]	2018	20		60.9 (8.1)	91.4 (6.9)	30.5	62.5 (10.1)	94.1 (7.4)	31.6
Xu et al.[6]	2019	28		67.3 (10.6)	96.3 (6.0)	29	n/a	n/a	n/a
Suture tape augmentation									
Xu et al.[6]	2019	25		68.2 (9.5)	97.5 (3.3)	29.3	n/a	n/a	n/a

n/a, not available.

*All values are reported as mean (standard deviation).

Table 4. Radiographic Outcomes Measured Pre- and Postsurgery, by Study

Author	Year	N	Graft Type	Anterior Drawer, mm		Difference	Talar Tilt, °		Difference
				Preoperative*	Postoperative		Preoperative	Postoperative	
Graft reconstruction									
Autograft									
Miyamoto et al.[16] (immobilized group)	2014	15	Gracilis	7.7 (1.8)	4.0 (1.6)	3.7	8.7 (2.6)	3.8 (1.5)	4.9
Miyamoto et al.[16] (accelerated group)	2014	20	Gracilis	8.7 (2.1)	4.3 (1.2)	4.4	10.5 (3.4)	4.3 (1.8)	6.2
Park et al.[18]	2016	30	Peroneus Longus	10.2 (3.3)	6.3 (1.9)	3.9	15.3 (6.2)	3.4 (3.0	11.9
Ventura et al.[23]	2018	20	Peroneus Brevis	7.8 (1.5)	1.4 (0.9)	6.4	11.9 (2.4)	2.4 (2.1)	9.5
Wang et al.[19]	2013	25	Semitendinosus	12.3 (3.0)	4.6 (1.8)	7.7	14.0 (3.7)	3.8 (1.8)	10.2
Xu et al.[6]	2014	32	Semitendinosus	(n/a)	(n/a)	(n/a)	14.0 (3.2)	3.8 (1.2)	10.2
Allograft									
Nakata et al.[17]	2000	20	Fascia lata	9.2 (3.9)	4.4 (2.5)	4.8	12.3 (4.2)	5.9 (3.0)	6.4
Wang et al.[20]	2017	19	Semitendinosus	9.8 (1.0)	4.0 (1.0)	5.8	17.3 (3.6)	4.2 (1.1)	13.2
Xu et al.[6]	2014	36	Unspecified	(n/a)	(n/a)	(n/a)	13.0 (3.5)	3.6 (1.4)	9.4
Youn et al.[21]	2012	14	Semitendinosus	10.1 (3.3)	7.2 (2.7)	2.9	15.5 (4.4)	7.3 (3.6)	8.2
Primary repair									
Cho et al.[26] (suture anchor group)	2012	20		8.2 (1.9)	4.2 (1.1)	4.0	17.2 (4.9)	5.9 (2.5)	11.3
Cho et al.[26] (transosseous suture group)	2012	20		8.4 (2.3)	4.1 (1.2)	4.3	15.8 (5.1)	5.4 (1.9)	10.4
Cho et al.[27]	2015	24		13.3 (n/a)	4.8 (n/a)	8.5	15.4 (n/a)	4.9 (n/a)	10.5
Jarvela et al.[32] (anatomic reconstruction)	2002	15		10.3 (1.3)	8.6 (2.4)	1.7	n/a	n/a	n/a
Jarvela et al.[32] (primary repair)	2002	17		11.9 (2.1)	8.0 (1.8)	3.9	n/a	n/a	n/a
Jeong et al.[34] (stress +)	2016	35		7.0 (2.2)	5.1 (7.7)	1.9	14.4 (4.2)	5.4 (3.4)	9.0
Jeong et al.[34] (stress −)	2016	10		6.6 (1.4)	4.7 (2.7)	1.9	4.8 (2.6)	3.0 (1.5)	1.8
Karlsson et al.[38] DM (I)	1995	20		10.2 (n/a)	7.2 (n/a)	3.0	9.5 (n/a)	4.2 (n/a)	5.3
Karlsson et al.[38] EM (II)	1995	20		10.7 (n/a)	6.7 (n/a)	4.0	8.8 (n/a)	3.7 (n/a)	5.1
Karlsson et al.[37] DM (A)	1999	15		11.0 (n/a)	6.5 (n/a)	4.5	10.0 (n/a)	4.0 (n/a)	6.0
Karlsson et al.[37] EM (B)	1999	15		10.5 (n/a)	5.0 (n/a)	5.5	9.0 (n/a)	4.0 (n/a)	5.0
Matsui et al.[41] (open technique)	2016	18		8.4 (n/a)	3.2 (n/a)	5.2	10.0 (n/a)	3.2 (n/a)	6.8
Matsui et al.[41] (arthroscopic)	2016	19		9.1 (n/a)	2.9 (n/a)	6.2	9.9 (n/a)	2.9 (n/a)	7.0
Messer et al.[42]	2000	22		7.0 (2.1)	2.7 (1.5)	4.3	10.1 (4.4)	4.5 (1.2)	5.6
Saragaglia et al.[46]	1997	32		8.2 (n/a)	6.5 (n/a)	1.7	14.5 (n/a)	6.0 (n/a)	8.5
Schmidt et al.[2]	2004	32		8.9 (2.0)	6.9 (2.6)	2.0	10.3 (4.1)	5.3 (3.9)	5.0
Trichine et al.[47]	2017	38		13.2 (n/a)	4.0 (n/a)	9.2	15.2 (n/a)	3.8 (n/a)	11.4
Ventura et al.[23]	2018	20		8.9 (1.3)	5.7 (1.1)	3.2	12.2 (2.3)	1.9 (1.4)	10.8
Xu et al.[6]	2019	28		12.2 (3.9)	3.1 (1.3)	9.1	14.2 (3.5)	2.7 (1.4)	11.5
Suture tape augmentation									
Cho et al.[48]	2015	34		12.4 (5.1)	4.1 (2.8)	8.3	16.3 (5.4)	4.5 (3.5)	11.8
Cho et al.[49]	2017	28		12.1 (5.5)	4.2 (2.8)	7.9	16.2 (5.1)	3.6 (2.2)	12.6
Xu et al.[6]	2019	25		12.2 (3.6)	2.9 (1.6)	9.3	14.0 (3.2)	2.4 (1.3)	11.6

DM, delayed mobilization; EM, early mobilization; n/a, not available.

*All values reported as mean (standard deviation).

Table 5. Reported Time to Return to Sports, by Study

Author	Year	N	Return to Sports (Weeks)	Range (Weeks)
Primary repair				
Agoropoulos et al.[24]	1997	75	20	17.4-26.1
Buerer et al.[8]	2013	41	20.4	8.7-52.1
Karlsson et al.[37] DM (I)	1995	20	12.5	n/a
Karlsson et al.[37] EM (II)	1995	20	9.5	n/a
Karlsson et al.[38] DM (A)	1999	15	13.0	10-17
Karlsson et al.[38] EM (B)	1999	15	10.0	7-12
Matsui et al.[41] (open technique)	2016	18	16.5	12-22
Matsui et al.[41] (arthroscopic)	2016	19	17.1	13-22
Saragaglia et al.[46]	1997	32	19.5	n/a
Trichine et al.[47]	2017	38	20.4	8.7-52.1
Suture tape augmentation				
Cho et al.[48]	2015	34	10.6	n/a

DM, delayed mobilization; EM, Early mobilization; n/a, not available.

GR 4.9-13.2°, PR 1.8-11.5°, and STA 11.6-12.6°. Ventura et al.[21] found no significant difference in talar tilt measurements between their GR and PR groups. Xu et al.[6] found no significant difference in talar tilt measurements between their PR and STA groups.

Return to Sport (RTS)

Mean days RTS was reported in 8 studies[8,22,35,36,39,44,45,47] and included 327 participants (Table 5). Only one study[47] reported RTS for the STA technique, n = 34; 7 were PR,[8,22,35,36,39,44,45] n = 293; none of the GR studies reported weeks to RTS in their findings. The one STA study reported RTS at 10.6 weeks. The PR group ranged from 9.5-20.4 weeks. No comparative studies used RTS as a measured outcome.

Complications, Skin Wounds, Reoperation

Complications are summarized in Table 6. When we compared the overall complication rate ranges among the 3 techniques, the GR group had an overall complication rate range of 0% to 10%, PR had 0% to 23.1%, and STA was 2.9% to 17.9%. GR reported a skin wound rate range of 0%, whereas PR reported 0% to 8.1%, and STA reported 0% to 9.1%. Range of rates of reoperation for GR was 0%, PR 0% to 8%, and STA 0% to 2.9%.

Among the comparative studies, Giannini et al.[15] and Ventura et al.[21] reported no complications in either their GR group or PR group. Porter et al.[42] compared PR with STA. They reported 8% complications in PR group compared with 13.6% in STA (2/25 vs 3/22, respectively). They had 4% skin wounds in PR compared with 9.1% in STA (1/25 vs 2/22). They had 8% (2/25) reoperation rate for the PR group compared with 0 for the STA group. Xu et al.[6] also compared PR with STA and reported 7.1% (2/28) complications in PR compared with 12% (3/28) in STA. They had 3.6% (1/28) skin wounds in PR compared with 0% in STA. Finally, they had a 3.6% (1/28) reoperation rate for the PR group compared with 0% for the STA group.

Meta-Analyses: Functional Measures

A series of forest plots were constructed to compare SMDs on functional (Fig 6 A and B) and radiographic measures (Fig 7 A and B). Results for AOFAS are shown in Figure 6A; GR: 3.99, 95% CI 3.44-4.55 versus PR: 3.24, 95% CI 2.34-4.13 versus 4.06, 95 CI 3.06-5.05. Heterogeneity as measured by I^2 ranged from 17% in GR to 75% in PR indicating high variability among study results. While all studies showed improvement in AOFAS (which was significant for PR), there were little differences observed by surgery type as indicated by overlapping confidence intervals for SMD. However, only one study was included in STA; therefore, the random effects model was not applicable. Moreover, it is important to note that Higgins and Thompson, 2014 report that meta-analysis of less than 10 studies may be underpowered and may not yield reliable results. Regardless, the overall estimate for the standardized effect size of AOFAS was $I^2 = 69\%$, SMD = 3.81, 95% CI 3.45-4.15, $P = .16$. indicating no significant improvement observed among these studies. Similar results were found among studies reporting Karlsson Scores, although STA was not applicable: $I^2 = 49\%$, SMD = 4.08, 95% CI 3.72-4.45, $P = .31$.

Meta-Analyses: Radiographic Measures

Likewise, forest plots with standardized mean differences were conducted for radiographic measures. Anterior drawer measures (Fig 7A) all showed high heterogeneity among studies with significant differences observed within the 3 surgery types: GR $I^2 = 89\%$, $P < .01$; PR $I^2 = 91\%$, $P < .01$, STA $I^2 = 75\%$, $P = .02$. However, the overall effects were not significant, $I^2 = 90\%$, $P < .73$, SMD = −2.62, 95% CI −3.07 to −2.16. Results for talar tilt (Fig 7B) were nearly the same, $I^2 = 84\%$, $P < .80$, SMD = −3.18, 95% CI −3.59 to − 2.77.

Because I^2 among the studies was almost always high, and few STA surgery type studies were included, these meta-analyses results should be reviewed with caution. Future research may want to consider meta-regression techniques to compensate for high variability among studies, while limiting comparisons to graft reconstruction versus primary repair.

Discussion

This systematic review demonstrates that all 3 surgical techniques have favorable postoperative outcomes. In

Table 6. Complications by Operative Technique

Author	Year	N	Complications n	Complications %	Skin Wounds n	Skin Wounds %	Reoperation n	Reoperation %
Graft reconstruction								
Cho et al.[48]	2015	21	0	0	0	0	0	0
Miyamoto et al.[16]	2014	33	0	0	0	0	0	0
Nakata et al.[17]	2000	20	0	0	0	0	0	0
Park et al.[18]	2016	30	0	0	0	0	0	0
Sammarco et al.[4]	1999	30	3	10	0	0	0	0
Ventura et al.[23]	2018	20	0	0	0	0	0	0
Wang et al.[19]	2013	25	0	0	0	0	0	0
Wang et al.[20]	2017	19	1	5.3	0	0	0	0
Xu et al.[6]	2014	68	0	0	0	0	0	0
Youn et al.[21]	2012	14	0	0	0	0	0	0
Total graft reconstruction		280	4	1.4	0	0	0	0
Primary repair								
Agoropoulos et al.[24]	1997	75	0	0	0	0	0	0
Alghern et al.[25]	1989	76	0	0	0	0	0	0
Brodsky et al.[5]	2005	73	3	4.1	0	0	0	0
Buerer et al.[8]	2013	41	0	0	0	0	0	0
Burn et al.[10]	2013	41	0	0	0	0	0	0
Cho et al.[26,27]	2012	40	7	17.5	2	5.0	0	0
	2015	24	2	8.3	1	4.2	0	0
Evans et al.[28]	1984	50	9	18	0	0	0	0
Giannini et al.[13]	2014	17	0	0	0	0	0	0
Gould et al.[29]	1980	50	1	2	0	0	0	0
Hamilton et al.[30]	1993	27	0	0	0	0	0	0
Iwao et al.[31]	2014	10	0	0	0	0	0	0
Jarvela et al.[32]	2002	32	2	6.3	0	0	0	0
Jaskulka et al.[33]	1988	268	2	0.7	2	0.7	2	0.7
Jeong et al.[34]	2016	45	0	0	0	0	0	0
Karlsson et al.[35-38]	1988	148	6	4.1	0	0	0	0
	1989	60	3	5.0	0	0	2	3.3
	1995	40	2	5.0	2	5.0	0	0
	1999	30	1	3.3	1	3.3	0	0
Keller et al.[390]	1996	39	9	23.1	2	5.1	0	0
Lofvenberg et al.[40]	1994	27	0	0	0	0	0	0
Matsui et al.[41]	2016	37	6	16.2	3	8.1	0	0
Messer et al.[42]	2000	22	2	9.1	1	4.5	0	0
Petrera et al.[43]	2014	49	3	6.1	2	4.1	0	0
Porter et al.[44]	2019	25	2	8	1	4	2	8
Russo et al.[45]	2016	18	0	0	0	0	0	0
Saragaglia et al.[46]	1997	32	2	6.3	1	3.1	0	0
Schmidt et al.[2]	2004	32	1	3.1	1	3.1	0	0
Trichine et al.[47]	2017	38	0	0	0	0	0	0
Ventura et al.[23]	2018	20	0	0	0	0	0	0
Xu et al.[6]	2019	28	2	7.1	1	3.6	1	3.6
Total primary repair		1514	65	4.3	20	1.3	7	0.5
Suture tape augmentation								
Cho et al.[48]	2015	34	1	2.9	0	0	1	2.9
Cho et al.[49]	2017	28	5	17.9	1	3.6	0	0
Porter et al.[44]	2019	22	3	13.6	2	9.1	0	0
Xu et al.[6]	2019	25	3	12	0	0	0	0
Total suture tape augmentation		109	12	11.0	3	2.8	1	0.9

regard to PR versus GR, all studies demonstrated improvements in AOFAS and Karlsson scores, suggesting that both techniques are viable options. Among the cohort studies comparing between surgical techniques, there were no differences in functional outcomes, measured by AOFAS or Karlsson scores.[13,21] The one study that compared AOFAS scores between PR and STA groups found no significant difference between preoperative and postoperative scores.[48] None of the studies in the STA group used Karlsson measurements in their outcomes. When looking at radiographic outcomes (anterior drawer and talar tilt), all surgical techniques demonstrated improvement. Xu et al.[6] found that there was no difference in anterior drawer or talar tilt

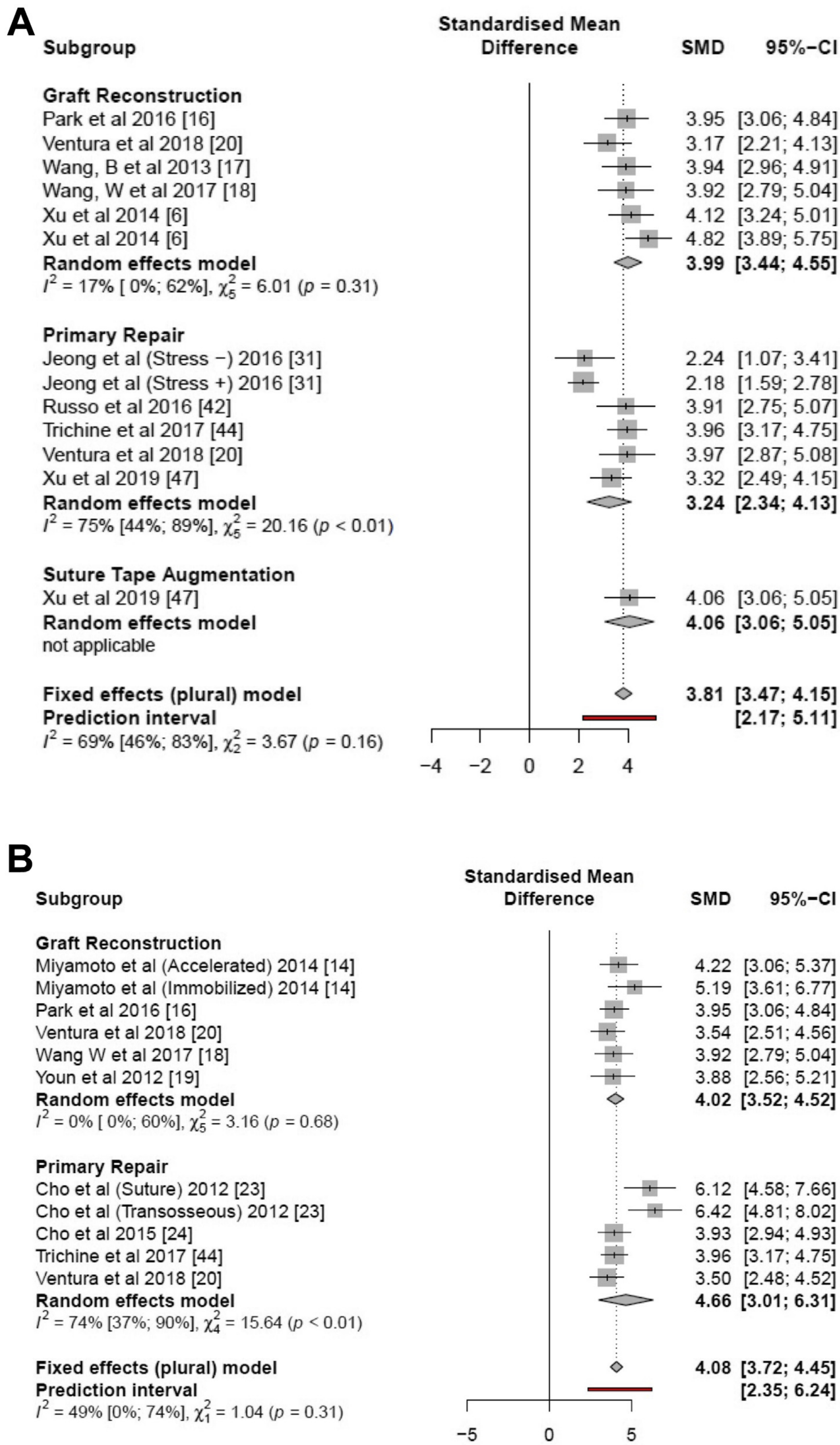

Fig 6. (A) Forest plot of our AOFAS mixed-effects model: pre- and postoperative measures. (B) Forest plot of our Karlsson Scores mixed-effects model pre- and postoperative measures. (AOFAS, American Orthopaedic Foot Ankle Score.)

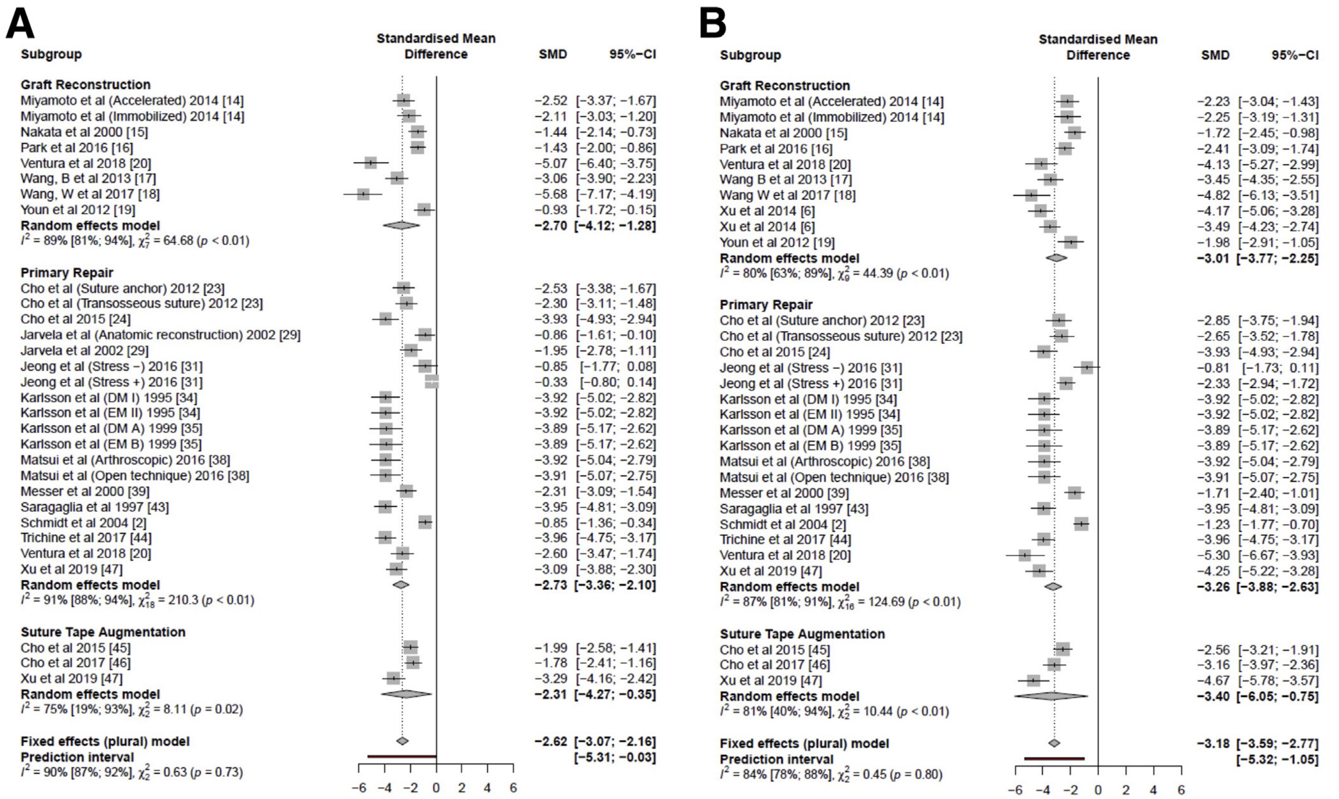

Fig 7. (A) Forest plot of our anterior drawer mixed-effects model pre- and postoperative. measures. (B) Forest plot of our talar tilt mixed-effects model pre- and postoperative measures.

outcomes between the PR and STA groups. Although Ventura et al.[21] found that the GR technique to have increased postoperative stability, as measured by anterior drawer, they found no significant difference in talar tilt. However, currently there is no study that directly evaluates for RTS and compares STA to either PR or GR.

Porter et al.[42] compared PR with STA and used the Foot and Ankle Outcome Score and Tegner score. They found STA to have statistically significant better outcomes compared with their PR group. However, we did not use either of these measurements due to their being less commonly used. This further emphasizes the necessity to have a standard measurement tool for functional ankle outcomes.

Furthermore, 2 studies[13,21] did not find any significant difference in AOFAS scores between GR and PR. These studies demonstrate results which indicate that repair and reconstruction are both effective methods for lateral ankle ligament surgery. The study conducted by Byung-Ki Cho et al.[7] and colleagues using the STA demonstrated results indicating this augment is a viable technique for repair in which the Broström repair would not be optimal, such as a ligament with excessive laxity. Our study showed significant improvement in both mean talar tilt angle and anterior talar translation at final follow up. However, no current studies used radiographic outcomes to compare STA with PR or GR.

Cho et al.[49] used STA and showed that the average RTS was 10.6 weeks (n = 68), whereas Buerer et al.[8] used PR and showed an average RTS of 20.4 weeks. There were no comparative cohort studies that measured RTS. Hence, this may illustrate that STA could provide the benefit of athletes to RTS sooner than patients treated in PR. However, like we previously stated there are no current studies looking at RTS in the GR. Furthermore, more studies are needed to see if STA would provide benefit over patients treated with GR. Thus, to more definitively make recommendations on RTS, randomized controlled trials are needed.

Overall, low rates of complications were seen. No cohort study statistically analyzed differences in complication rates. Porter et al.[42] did find a greater rate of complications in their STA group compared with the PR group, although it is unclear if this is statistically significant. It is plausible that comorbid conditions had a modifying role in complication rates, not solely the surgical technique. More in-depth, randomized trials would be needed to determine if complications are more common for any particular surgical technique.

Furthermore, future studies are needed with a large comparable patient population to draw any strong statistical conclusions between the differing surgical techniques available for lateral ankle ligament injuries. In addition, future studies should also determine ideal postoperative rehabilitation protocols for these differing techniques respectively, in particular STA due to it being a relatively newer technique. Thus, like many fields of orthopaedics, a more standardized recording of function outcomes and greater-level evidence of randomized control studies assessing these different surgical techniques are needed to justify which technique is more superior.

Limitations

Our study does contain significant limitations which must be addressed. One is the heterogenous distribution of patients analyzed among the different arms of the study (31 studies for PR vs 10 studies for GR vs 4 studies for STA). Thus, due to this heterogenous distribution and there being limited high-level evidence directly evaluating these different surgical techniques, a more formal meta-analysis was unable to be performed. Hence, further limiting our systematic review with majority of case series, which limits our conclusion drawn from this study. Also, there were varying surgical techniques within the 3 groups that also limited the ability to directly compare the three groups. For example, if lateral ankle ligament repairs were performed using differing novel techniques as well as intrinsic differences in autograft/allograft quality in the reconstruction arm. Another limitation is that outcome measures were not standardized across studies or there was a wide variety of functional outcomes reported, in which we illustrated in Figure 1, hence, decreasing the patient population available for direct comparison and limiting any meta-analysis in the future. Another limitation to this study was due to the poorly defined patient selection in patients suffering from acute versus chronic injuries. We were unable to differentiate our outcomes between acute versus chronic injuries that underwent surgeries. Thus, this could have also skewed overall final results. Finally, Karlsson and AOFAS scores were used in this analysis because they were reported the most frequently in the current literature. However, neither of these functional outcome scores have been validated for lateral ankle instability and its corresponding treatments.

Conclusions

Excellent outcomes were noted across all intervention groups. Current literature may suggest there is no difference in functional outcomes between patient's treated with PR versus GR. However, there may be a potential improvement in functional outcomes with PR versus STA.

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