Meta-Analysis

Similar Outcomes Are Found Between Quadriceps Tendon Repair With Transosseous Tunnels and Suture Anchors: A Systematic Review and Meta-Analysis

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Purpose: To evaluate the clinical outcomes and biomechanical performance of transosseous tunnels compared with suture anchors for quadriceps tendon repair. **Methods:** In accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, a systematic search was performed in April 2021 in the following databases: Cochrane Database of Systematic Reviews, PubMed (1980-2021), MEDLINE (1980-2021), Embase (1980-2021), and CINAHL (1980-2021). Level I-IV studies were included if they provided outcome data for surgical repair of the quadriceps tendon using transosseous tunnels or suture anchors with minimum 1-year follow-up. Biomechanical studies comparing transosseous tunnels and suture anchors were separately analyzed. **Results:** The systematic search yielded 1,837 citations, 23 of which met inclusion criteria (18 clinical, 5 biomechanical). In total, 13 studies reported results for transosseous repair and 7 studies reported results for repair with suture anchors. There were results for 508 patients from clinical studies. The average postoperative Lysholm score ranged from 88 to 92 for suture anchor repairs and 72.8 to 94 for transosseous repairs with range of motion ranging from 117° to 138° and 116° to 135°, respectively. Synthesis of the biomechanical data revealed the mean difference in load to failure was not significant between constructs (137.21; 95% confidence interval −10.14 to 284.57 N; $P = .068$). **Conclusions:** Transosseous and suture anchor techniques for quadriceps tendon repair result in similar biomechanical and postoperative outcomes. No difference between techniques in regard to ultimate load to failure among comparative biomechanical studies were observed. **Level of Evidence:** Level IV, systematic review level III-IV studies.

Quadriceps tendon ruptures affect 1.37 per 100,000 people annually and can be devastating because of the central role that the tendon plays in proper knee function.[1] Indirect trauma is the most common cause of quadriceps tendon rupture in healthy adults. Clinically, patients present following a fall and report significant knee swelling and an inability to extend the knee.[1] However, in adults with underlying conditions such as endocrine or rheumatic disease, cases of spontaneous or bilateral rupture have been reported.[2]

Although some partial tears can be treated conservatively, surgical quadriceps tendon repair (QTR) is

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recommended for most complete tears due to the functional limitations associated with an incompetent extensor mechanism.[3] Transosseous repair, which involves passing high tensile-strength suture through parallel tunnels drilled into the patella, is commonly used and has traditionally been considered the gold standard.[4] It is cost-effective and has a high success rate but is technically demanding and carries the risk for iatrogenic fracture of the patella and cartilage damage.[5,6] Suture anchors, although more expensive, require smaller incisions and less surgical dissection.[4,6]

To date, results of clinical and biomechanical data have been mixed, as some authors have reported superior results with one technique and others have found no difference. Hart et al.[7] found transosseous tunnels to be biomechanically superior, whereas Petri et al.[8] concluded that suture anchors were biomechanically favored. In contrast, Sherman et al.[6] and Lighthart et al.[9] did not see any significant differences between either repair method. Clinical outcomes have been more agreed upon, such as Elkin et al.[10] and Plesser et al.[4] not finding any significant differences between repair technique. However, Mehta et al.[11] did see favorability in the transosseous tunnel approach when it came to range of motion as well as a decreased postoperative rate of infection when compared with suture anchors. The purpose of this systematic review and meta-analysis was to evaluate the clinical outcomes and biomechanical performance of transosseous tunnels compared with suture anchors for QTR. We hypothesized that there would be no difference in clinical outcomes or biomechanical performance between repair constructs.

Methods

Design and Registration

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist and guidelines were observed throughout the design, analysis, and authorship of this work.[12] No institutional review board approval was required.

Search Strategy

A systematic search for articles published between 1980 and 2021 was carried out in the PubMed, Medline, Embase, Cochrane, and CINAHL databases using the terms “quadriceps tendon,” “quad tendon,” “suprapatellar tendon,” “tendon quadriceps,” “rupture,” “tear,” “avulsion,” “injury,” “rerupture,” “disruption,” “surgery,” “surgical,” “operative,” “management,” “operation,” “repair,” “reconstruction,” “revision,” “transosseous,” “suture anchor,” “bone tunnel,” “outcome,” “return to play,” “biomechanical,” and “technique” combined with the Boolean operators AND/OR. A final query was conducted in April 2021.

Study Selection

Titles of English-language studies evaluating QTR clinically and/or biomechanically were considered. Inclusion criteria were as follows: (1) reported outcomes or results following QTR (clinical or biomechanical), (2) minimum mean follow-up of 1 year (clinical studies), (3) minimum 5 patients (clinical studies), and (4) English-language results. Exclusion criteria included the following: (1) case reports and (2) review articles. Throughout the process, any disagreements were resolved by discussion among all the authors until a consensus agreement was achieved. Clinical studies reporting Lysholm score, postoperative knee ROM, or re-rupture rate following QTR with transosseous or suture anchor constructs, and biomechanical studies comparing load to failure between transosseous and suture anchor constructs, were identified by 4 of the authors (C.C., B.P.D., D.O.O., P.W.) and selected for qualitative and quantitative analysis.

The same 4 authors (C.C., B.P.D., D.O.O., P.W.) extracted the following data for all studies: article authorship, year of publication, journal, and level of evidence according to the American Academy of Orthopaedic Surgeons levels of evidence system.[13]

From clinical studies, these authors determined the number of patients and operated knees, age, sex, and follow-up, and collected relevant clinical outcomes (Lysholm score, postoperative range of motion, and failure/re-rupture). Any additional reported outcomes were likewise recorded for qualitative reporting. For biomechanical studies, the number of specimens was determined and load to failure performance was recorded for quantitative analysis.

Quality Assessment

Study quality and risk of bias were evaluated by 2 reviewers (B.P.D. and D.O.O.) with the MINORS (Methodological Index for Non-Randomized Studies) instrument,[14] a validated system for the assessment of bias and methodologic quality that has demonstrated utility in multiple orthopaedic sports medicine analyses.[15-18] The scores were averaged to obtain a final score for each study.

Statistical Methods

Analyses were conducted with the “metafor” and “meta” packages in R (Version 3.6.3; R Foundation for Statistical Computing, Vienna, Austria).[19] With clinical studies, quantitative analysis was not performed due to the heterogeneity of methodology within our included studies. Biomechanical studies were evaluated in a random effects model. Heterogeneity was evaluated with the Cochran Q test (random effects models) or Q_E (generalized/weighted least-squares extension for mixed effects models) and the corresponding P value, τ^2, and I^2. In mixed effects models, which include moderators, Q_E represents the residual heterogeneity (observed effect size variability unaccounted for by the moderators), whereas Q_M represents an omnibus test for observed effect size variability accounted for by all included coefficients.[20] Statistical significance was defined as $P < .05$.

Results

The search produced 1,836 potentially relevant abstracts after removing duplicates. Ultimately upon full-text review, there were 24 studies suitable for qualitative analysis (18 clinical, 6 biomechanical), with 4 biomechanical studies for quantitative analysis.[3,4,6-10,21-37]

Study Characteristics

Characteristics of the included studies are presented in Tables 1 and 2. Thirteen studies reported results for transosseous repair, and 7 studies reported results for repair with suture anchors. There were 11 Level IV studies and 7 Level III studies. The studies of both Elkin et al.[10] and Plesser et al.[4] were both comparative with results for transosseous and suture anchor repair. Overall, the average age of included subjects ranged from 34.2 to 81.4 years, and the majority of patients were male.[24,29] Reported follow-up in clinical studies ranged from 1 to 10.25 years.[31,35] Postoperative management strategies as reported by the included clinical studies are summarized in Table 3.

MINORS Analysis

The median averaged MINORS score of the included clinical studies was 10 (range, 5-15). Four of the included studies were comparative and had all 12 domains evaluated.

Results of Individual Studies

Clinical Studies

Patient-Reported Outcome Metrics (PROMs). Overall, both surgical techniques yielded favorable clinical results. Average postoperative Lysholm score ranged from 88 to 92 for suture anchor repairs and from 72.8 to 94 for transosseous repairs.[4,10,29] Both comparative studies reported clinical outcome scores. Elkin et al.[10] found no significant difference in Lysholm score between groups, with the suture anchor group reporting a mean Lysholm of 63, and the transosseous repairs group reporting a mean Lysholm of 72.8. Similarly, Plesser et al.[4] found no difference between groups in terms of Lysholm, Tegner, International Knee Documentation Committee, or visual analog scale score at final follow-up.

Repair Failure/Re-rupture. Six of the included studies, 3 of suture anchor repair and 3 with results of transosseous repairs, reported no reruptures.[22,25,29,32,36,37] Among studies with transosseous results, Konrath et al.[27] reported 1 re-rupture in a patient who fell 4-months after surgery. Langenhan et al.[28] observed 2 re-ruptures (8%) in a group that received traditional, restrictive rehabilitation, and 2 re-ruptures (5%) in the functional rehabilitation group. Negrin et al.[31] reported 7 re-ruptures (8%) that occurred at various time points postoperatively. Among studies with suture anchor results, Mille et al.[30] documented re-ruptures in 2 patients who deviated from postoperative protocols. In their comparative study, Elkin et al.[10] noted 1 re-rupture (9%) in the suture anchor group and 3 re-ruptures (14%) in the transosseous group.

Range of Motion. Twelve of the included studies reported range of motion.[4,10,21,22,24,25,27,29,30,35-37] The range for mean arc of motion following transosseous repairs and suture anchor repair was 116° to 135° and 117° to 138°, respectively (Fig 1). Elkin et al.[10] directly compared the suture anchor technique with the transosseous technique and found no significant difference in outcomes. Overall, both techniques were found to yield satisfactory outcomes. More broadly, Marzouki et al.[29] compared suture anchor repair with repair using a simple suture and wire augmentation and found that there was no significant difference in ROM.

Biomechanical Studies

Results of individual biomechanical studies are presented in Table 2. One study by Hart et al.[7] found that a novel double-row suture anchor construct had inferior ultimate load to failure compared with transosseous repair. (This study was not included in the quantitative analysis due to the novel nature of the suture anchor construct.) Conversely, 2 studies found suture anchor repair to be biomechanically superior. Petri et al.[8] found that suture anchor repair produced less gap formation during cyclic loading and had a higher ultimate load to failure, whereas Sherman et al.[6] found no difference in ultimate load to failure but significantly less gap formation during cyclic loading with suture anchor constructs. Kindya et al.[3] compared 3 types of repair and found that knotless suture anchors with suture tape produced superior biomechanical results in cyclic displacement and ultimate load to failure when compared to transosseous and fully-threaded suture anchor repair. Two studies reported no difference in biomechanical performance between techniques.[9,34]

Biomechanical Studies Quantitative Analysis

Four studies directly compared load-to-failure performance of transosseous and suture anchor QTR constructs on a total of 106 specimens (48 transosseous repairs, 58 suture anchor repairs).[3,6,8,34] The mean

Table 1. Characteristics of Included Clinical Studies

Article			Study Design	LOE	No. of Patients*	Technique, n†		Age, y‡		Male: Female Sex, n		Follow-up, y (Range/SD)‡	
Author	Year	Journal				TO	SA	TO	SA	TO	SA	TO	SA
Boudissa et al.[21]	2014	*Orthop Traumatol Surg Res*	Retrospective case series	4	65	25	0	55.2 ± 13.9	NA	NR	NA	6.3 ± 5.6	NA
Brossard et al.[22]	2017	*Orthop Traumatol Surg Res*	Retrospective cohort	4	22	25	0	64 (52-87)	NA	17:5	NA	7 (3-9)	NA
De Baere et al.[23]	2002	*Acta Orthop Belg*	Retrospective case series	4	24	24	0	58 (13-85)	NA	21:3	NA	6.3 (0.25-24)	NA
Elkin et al.[10]	2016	*J Arthrosc Jt Surg*	Retrospective cohort	3	27	22	11	49 (33-68)	54 (35-74)	15:2	8:2	1.26 (0.16-5.8)	0.5 (0.21-0.95)
Ellanti et al.[24]	2016	*Muscles Ligaments Tendons J*	Retrospective case series	4	6	6	0	81.4 (80.3-82.08)	NA	5:1	NA	4.5 (3.5-6.1)	NA
Hantes et al.[25]	2019	*Orthop Traumatol Surg Res*	Retrospective cohort	3	13	13	0	54.6 (48-67)	NA	10:3	NA	5.8 (3.3-10.7)	NA
Huleatt et al.[26]	2019	*Tech Orthop*	Retrospective cohort	4	36	0	36	NA	55	NA	31:5	NA	3.6§
Konrath et al.[27]	1998	*J Orthop Trauma*	Retrospective case series	4	48	48	0	56 (21-79)	NA	NR	NA	4 (1.1-17)	NA
Langenhan et al.[28]	2012	*Knee Surg Sports Traumatol Arthrosc*	Retrospective cohort	3	66	63	0	60.7 ± 11.4	NA	59:7	NA	4.5 ± 1.7	NA
Marzouki et al.[29]	2018	*Ann Orthop Musculoskelet Disord*	Prospective case series	3	12	0	6	NA	34.2 (25-48)	NA	8:4	NA	2.5 (1.3-3.5)
Mille et al.[30]	2016	*Eur J Orthop Surg Traumatol*	Prospective case series	4	11	0	11	NA	65.8 ± 11.7	NA	11:0	NA	1.2 ± 0.35
Negrin et al. [31]	2015	*Injury*	Retrospective cohort	4	90	90	0	61.1 (13-90)	NA	79:11	NA	10.25 ± 4	NA
O'Shea et al.[32]	2001	*Injury*	Retrospective case series	4	19	0	19	NA	55.7	NA	16:3	NA	1.89 (1-5.1)
Plesser et al.[4]	2018	*PLoS One*	Prospective cohort	3	17	8	9	57.9 ± 12.7	62.7 ± 8.8	8:0	9:0	2.4 ± 0.58	3.8 ± 1.4
Rougraff et al.[33]	1996	*Orthopedics*	retrospective	3	44	16	0	56.8	NA	NR	NA	5.6 (2-22)	NA
Tejwani et al.[35]	2012	*J Orthop Trauma*	Retrospective case control	3	36	36	0	57.5	NA	34:2	NA	NR (1-6.7)	NA
Verdano et al.[36]	2014	*Muscles Tendons Ligaments J*	Retrospective case series	4	20	20	0	54 (42-59)	NA	20:0	NA	3 (2.1-4)	NA
Wenzl et al.[37]	2003	*Injury*	Retrospective case series	4	35	30	0	53.3	NA	33:2	NA	4.6 (0.6-14)	NA

LOE, level of Evidence; NA, not applicable; NR, not reported; SA, suture anchor; SD, standard deviation; TO, transosseous.

*Reflects the number of included patients with transosseous or suture anchor repairs as reported by the studies. Some patients in some studies had bilateral repairs.

†May differ from reported number of patients due to loss to follow-up or bilateral repairs in some patients.

‡Average ± SD or average (range).

§No variance metrics reported.

Table 2. Characteristics and Results of Included Biomechanical Studies

Article							
Author	Year	Journal	Technique	No. of Anchors Used	No. of Specimen	Findings	Conclusions
Hart et al.[7]	2012	*J Knee Surg*	TO		5	Cyclic displacement: 8 ± 3 mm Stiffness: 132 ± 15 N/mm Ultimate load: 591 ± 84 N	Double-row suture anchor has less strength compared with transosseous repair
			SA	4 (2P,2D)	6	Cyclic displacement: 8 ± 4 mm Stiffness: 134 ± 26 N/mm Ultimate load: 447 ± 86 N	
Kindya et al.[3]	2017	*Arthroscopy*	TO		10	Displacement cycle 1-20: 6.3 ± 1.9 mm Displacement cycle 20-250: 3.1 ± 0.9 mm Ultimate load: 413 ± 107 N Stiffness: 26 ± 12 N/mm	Repair using knotless suture anchor w/suture tape superior to suture anchor or transosseous repair
			SA (knotless anchor + suture tape; matched to TO)	2	10	Displacement cycle 1-20: 3.6 ± 1.3 mm Displacement cycle 20-250: 2.0 ± 0.4 mm Ultimate load: 616 ± 149 N Stiffness: 67 ± 25 N/mm	
			SA (standard)		10	Displacement cycle 1-20: 5.1 ± 0.9 mm Displacement cycle 20-250: 2.3 ± 0.5 mm Ultimate load: 399 ± 87 N Stiffness: 28 ± 10 N/mm	
			SA (knotless anchor + suture tape; matched to standard SA)	2	10	Displacement cycle 1-20: 3.0 ± 0.8 Displacement cycle 20-250: 1.9 ± 0.5 Ultimate load: 579 ± 129 Stiffness: 62 ± 20	
Lighthart et al.[9]	2008	*Orthopedics*	TO		11	Lateral displacement (10 cycles): 2.1 ± 0.4 mm Medial displacement (10 cycles): 1.7 ± 0.5 mm Lateral displacement (1,000 cycles, no load): 3.4 ± 0.3 mm Medial displacement (1,000 cycles, no load): 4.2 ± 0.6 mm Lateral displacement (1,000 cycles, load): 4.2 ± 0.3 mm Medial displacement (1,000 cycles, load): 4.8 ± 0.6 mm	No difference between transosseous repair or repair using suture anchors
			SA	3	11	Lateral displacement (10 cycles): 2.6 ± 0.3 mm Medial displacement (10 cycles): 2.1 ± 0.4 mm Lateral displacement (1,000 cycles, no load): 4.1 ± 0.4 mm Medial displacement (1,000 cycles, no load): 3.3 ± 0.4 mm Lateral displacement (1,000 cycles, load): 5.0 ± 0.4 mm Medial displacement (1,000 cycles, load): 4.3 ± 0.5 mm	
Petri et al.[8]	2015	*Knee Surg Sports Traumatol Arthrosc*	TO		10	Elongation (1-20 cycles): 12.2 ± 3.2 mm Elongation (20-250 cycles): 33.3 ± 1.9 mm Maximum load failure: 338 ± 60 N	Repair with suture anchor superior to transosseous repair
			SA (titanium)	2	10	Elongation (1-20 cycles): 3.2 ± 0.5 mm Elongation (20-250 cycles): 1.9 ± 0.1 mm Maximum load failure: 740 ± 204 N	
			SA (hydroxyapatite)	2	10	Elongation (1-20 cycles): 3.9 ± 0.8 mm Elongation (20-250 cycles): 1.5 ± 0.5 mm Maximum load failure: 572 ± 67 N	

(continued)

Table 2. Continued

Article							
Author	Year	Journal	Technique	No. of Anchors Used	No. of Specimen	Findings	Conclusions
Sellei et al.[34]	2015	*Knee*	TO		12	Load to discontinuity: 266.75 ± 82.61 N Load to failure: 353.08 ± 72.07 N Stiffness: 6.66 ± 3.32 N/mm	Transosseous fixation showed comparable results with the suture anchor system
			SA	2	12	Load to discontinuity: 290.88 ± 106.01 N Load to failure: 352.68 ± 116.27 Stiffness: 9.83 ± 7.75 N/mm	
Sherman et al.[6]	2016	*Arthroscopy*	TO		6	Elongation after first 100 cycles: 4.7 mm (3.3-6.1 mm) Elongation after another 10 cycles at 50-150 N: 7.4 mm (4.5-10 mm) Elongation after another 10 cycles at 50-250 N: 9.1 mm (6.6-11.4 mm) Elongation after another 10 cycles at 50-250 N: 10.7 mm (8.9-12.9 mm) Ultimate load to failure: 250.5 ± 42 N	Suture anchor significantly less gaping during cyclic loading; no difference in load to failure
			SA	3	6	Elongation after 100 cycles: 2.7 mm (range, 2.2-3.9 mm) Elongation after another 10 cycles at 50-150 N: 5.1 mm (4.7-5.7 mm) Elongation after another 10 cycles at 50-250 N: 6.4 mm (5.7-7 mm) Elongation after another 10 cycles at 50-250 N: 7.7 mm (6.2-8.2 mm) Ultimate load to failure: 286 ± 86 N	

SA, suture anchor; TO, transosseous.

difference in load-to-failure was not significant between constructs (137.21; 95% confidence interval −10.14 to 284.57 N; $P = .068$; $Q = 37.52$ [$P < .001$]; τ^2 143.41; $I^2 = 92.00\%$) (Fig 2).

Risk of Bias Across Studies

Begg's rank test for publication bias was not significant for any of the clinical models examined, and Egger's regression test was significant for the Lysholm score analysis only ($P = .005$) For the biomechanical analysis, neither Begg's nor Egger's tests were significant (Begg's: Kendall's $\tau = 0.333$, $P = .750$; Egger's: $z = 0.718$, $P = .473$).

Discussion

The most important findings of this study were that the clinical outcomes of QTR with transosseous and suture anchor constructs were similar, and we observed no difference between techniques in ultimate load to failure among comparative biomechanical studies.

A recent systematic review by Mehta et al.[11] identified 8 studies with results for 210 repairs and yielded similar findings. When comparing results of transosseous and suture anchor repairs, the authors observed greater range of motion at final follow-up with transosseous repair but concluded that the difference was unlikely clinically relevant. The authors did not evaluate biomechanical results. By analyzing a larger body of literature, the findings of this study were able to expand upon this conclusion.

Many of the included studies used a variety of parameters to evaluate the clinical differences between transosseous and suture anchor repair. For example, Mille et al.[30] found that 100% of their study participants, all surgically treated with suture anchors, returned to preinjury activity level with a mean time for functional recovery of 3 months. Wenzl et al.[37] studied transosseous repair and came to a similar conclusion, with 91% of patients returning to work and most patients reporting a "good" or "excellent" outcome. Although additional studies analyzed quadriceps strength at final follow-up Elkin et al.[10] directly compared this parameter and found no significant difference between groups. However, other studies suggest that some level of residual strength deficit is common.[23,27]

The included biomechanical studies directly compared the performance of transosseous and suture anchor repair constructs. All reported ultimate load-to-failure characteristics, enabling a quantitative evaluation of the summary effect. There was no significant difference between repair constructs in ultimate load to failure. In addition, several studies discussed displacement and elongation. Lighthart et al.[9] measured displacement at various time points

Table 3. Postoperative Management and Rehabilitation Protocols

Article*	Timeline†	Immobilization	Weight-Bearing/ Ambulation	Activity/Therapy
Boudissa et al. (2014)[21]	0-6	Immobilized in leg cylinder cast	Immediate weight-bearing	NR
	6+	Removable brace until full, pain-free ROM	–	NR
De Baere et al. (2002)[23]	0-4.5	Immobilized in brace or plaster cast	NR	–
	>4.5	–	NR	Passive mobilization, 0°-90°; progress to >90°; progress to isotonic physiotherapy
Elkin et al. (2019)[10]	0-6	Immobilized in extension	Weight-bearing as tolerated	PROM
	7-12	–	–	AROM
	>12	–	–	Resistance training
Ellanti et al. (2016)[24]	0-2	Immobilization in full extension with brace	Full weight-bearing	NR
	3-6	–	ROM gradually increased	NR
Hantes et al. (2019)[25]	0-2	Immobilized long knee hinge brace		PROM, 0°-30°
	3-6	–	–	PROM, 0°-90°
	>6	–	–	Full ROM, active extension
Huleatt et al. (2019)[26]	0-2	Hinged brace in full extension; brace unlocked when not ambulating	Weight-bearing as tolerated	Flexion to 30°, passive extension, patellar mobility exercises
	3-6	–	–	PROM 0°-90° as tolerated
	7-8	–	–	Progressive quadricep strengthening
	≥16	–	–	Running and sport-specific training
	≥24	–	–	Jumping and contact sports permitted if strength 85%-90% of contralateral side
Konrath et al. (1998)[27]	0-6	ROM brace locked in extension	Partial weight-bearing with brace locked in extension	Prone active flexion exercises
	7-8	–	Full weight-bearing	Gait training with light resistance, increased flexion with ambulation as brace progressively unlocked
	9-12	–	–	Full flexion in brace, stationary biking
	13-15	–	–	Progressive resistance exercises
	≥16	Brace discontinued	–	Closed-chain exercises and light jogging; running, sprinting, and cutting exercises gradually added
Langenhan et al. (2012)[28]				
Group A	0-6	Hinged knee brace	Partial weight-bearing	PROM/AROM limited to 40°
Group B	0-2	Hinged knee brace to 30°	Full weight-bearing as tolerated	–
	3-4	Hinged knee brace to 60°	–	–
	5-6	Hinged knee brace to 90°	–	–
Marzouki et al. (2018)[29]	3-6	Brace	–	Active flexion up to 60°
	>6	–	Full weight-bearing	–
Mille et al. (2016)[30]	0-4	Removable splint	Immediate protected weight-bearing	Isometric quadriceps strengthening, PROM 0°-60°
	5-6	–	–	ROM to 90°

(continued)

Table 3. Continued

Article*	Timeline†	Immobilization	Weight-Bearing/ Ambulation	Activity/Therapy
	>6	–	–	Full ROM; gradual return to sport allowed at 3 months
Negrin et al. (2015)[31]	NR	Knee immobilizer or cylinder cast	Full weight-bearing	PROM exercises
O'Shea et al. (2001)[32]	0-6	Cylinder cast	Partial weight-bearing	–
	>6	–	–	ROM exercises
Plesser et al. (2018)[4]				
Transosseous	0-8	Cylinder cast	Partial weight-bearing encouraged starting postoperative day 2	–
Suture anchor	0-2	ROM brace locked in extension	Partial weight-bearing	40° continuous passive motion
	3-4	ROM brace to 40°	Full weight-bearing as tolerated	60° continuous passive motion
	5-6	ROM brace to 60°	–	90° continuous passive motion
Rougraff et al. (1996)[33]	NR	Varied‡	Varied‡	Varied‡
Tejwani et al. (2012)[35]	0-2	Immobilized (not further specified)	–	–
	3-6	–	Partial weight-bearing in extension	Limited ROM exercises
	>6	–	–	Full AROM
Verdano et al. (2014)[36]	0-4	Plaster cast in extension	–	–
	>4	–	–	Therapy to achieve full ROM
Wenzl et al. (2003)[37]	0-6	Varied§	Partial weight-bearing to 10 kg	–

NOTE. A dash (–) symbol indicates that no protocols for the given category were implemented for the stated time frame.
AROM, active range of motion; NR, not reported; PROM, passive range of motion; ROM, range of motion.
*Lead author last name (year of publication).
†Weeks from surgery.
‡"Postoperative physical therapy varied from early motion (in 3 patients) to knee extension cast for 3 to 6 weeks, followed by ROM exercises. Some patients had formal therapy; others had none."
§Treatment varied according to intraoperative findings. Early mobilization to 60° with continuous passive motion and assisting physical therapy was allowed for 21 patients in whom the repair tolerated flexion intraoperatively to 60°. Active extension allowed at 6 weeks. Fourteen patients in whom repairs did not tolerate intraoperative flexion to 60° were immobilized in a cast for 6 weeks.

throughout cyclic loading and found that there was no difference in medial or lateral displacement at any time point. Hart et al.[7] similarly found no difference in stiffness or gap formation, but did conclude that transosseous repair led to superior ultimate tensile load. Conversely, Sherman et al.[6] found that although there was no difference in ultimate load to failure, repair with suture anchors led to significantly less gap formation during cyclic loading. Previous systematic reviews have examined biomechanical differences in QTR using transosseous versus suture anchor. Both reviews concluded that cyclic displacement and load to failure were similar between techniques. Belk et al.'s systematic review concluded that quadriceps tendon repaired via the suture anchor technique have less initial displacement upon cyclic testing when compared to QTs repaired via the transosseous technique. However, final displacement and ultimate load to failure outcomes were similar between the 2 fixation strategies. Similarly, the analysis performed in the current study supports these findings. In a systematic review by Dankert et al.,[39] the authors found no significant difference in gap formation and load to failure between transosseous tunnels and suture anchors for QTR. Our study is unique due to the integration of

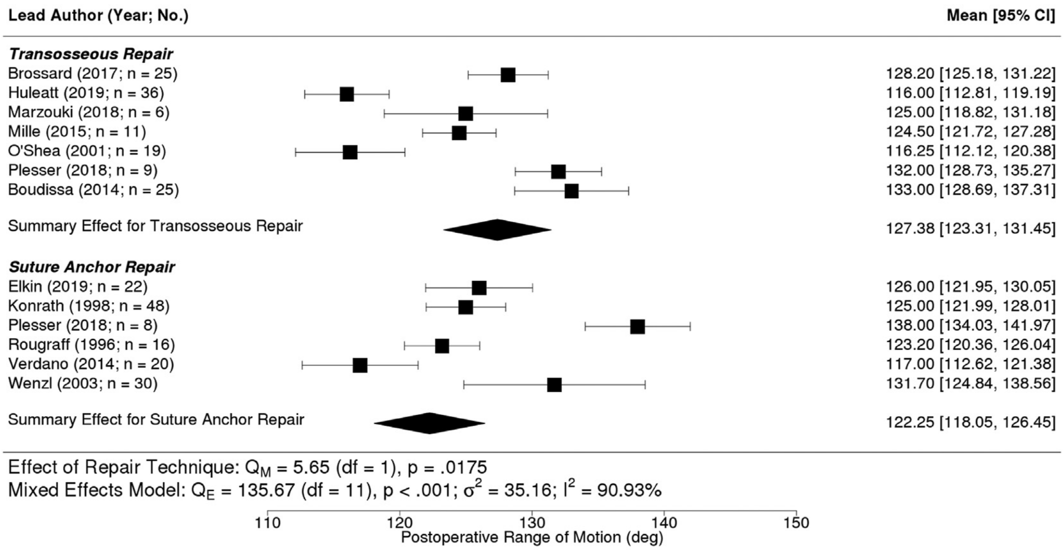

Fig 1. Forest plot illustrating reported range of motion (°) in transosseous and suture anchor repair. (CI, confidence interval.)

clinical data for a more powerful analysis. While we included 23 studies for our review, Belk et al.[38] and Dankert et al.[39] included 5 and 15, respectively. Although these 2 studies produced credible results using only biomechanical data, our use of clinical data with biomechanical results allows us to evaluate how the live human tissue contributes to the healing process after each surgical technique. Sole biomechanical data using human cadaveric tissue could not recreate this phenomenon. We were able to report clinical data with return-to-work levels, regain of quadriceps strength back to preinjury levels, and range-of-motion characteristics while using not only surgical technique, but timeline, immobilization, weight-bearing, ambulation and physical therapy protocols to asses similarity of study protocol. Although the data remain inconclusive in selecting a favorable repair method, the individual techniques provide sufficient biomechanical data to be adequate methods of QTR. Future high-quality comparative studies that control for known confounding variables are needed to conclude whether a clinically significant difference exists.

Limitations

This study is not without limitations. In the present analysis, most available clinical studies were Level IV evidence. Second, although all included biomechanical studies reported ultimate load to failure, there was some degree of heterogeneity in the methods and materials employed by these studies. In addition, all biomechanical studies represent ex vivo approximations of in vivo conditions, frequently of time-zero characteristics, and care must be taken when extrapolating results to actual surgeries in living patients. Finally, a quantitative analysis of the included clinical studies could not be performed due to the heterogeneity and low-level evidence presented in the included studies.

Conclusions

Transosseous and suture anchor techniques for QTR result in similar biomechanical and postoperative outcomes. No difference between techniques in regard to ultimate load to failure among comparative biomechanical studies were observed.

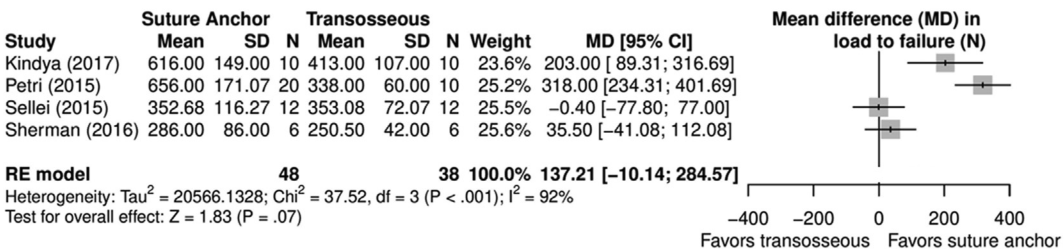

Fig 2. Forest plot illustrating no difference between transosseous and suture anchor constructs in biomechanical load to failure performance. (CI, confidence interval; SD, standard deviation.)

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