JSES Reviews, Reports, and Techniques 2 (2022) 332–339

Contents lists available at ScienceDirect

JSES Reviews, Reports, and Techniques

journal homepage: www.jsesreviewsreportstech.org

Surgical repair of distal triceps rupture: a systematic review of outcomes and complications

Danny V. Tran, MD[a,1], Thomas R. Yetter, MS[a], Jeremy S. Somerson, MD[b,*]

[a]School of Medicine, The University of Texas Medical Branch, Galveston, TX, USA
[b]Department of Orthopaedic Surgery and Rehabilitation, The University of Texas Medical Branch, Galveston, TX, USA

ARTICLE INFO

Keywords:
Arm injuries
Operative surgical procedures
Patient-reported outcome measures
Suture anchors
Tendon injuries
Transosseous bone tunnel
Triceps
Upper extremity

Level of evidence: Level IV; Prognostic Study

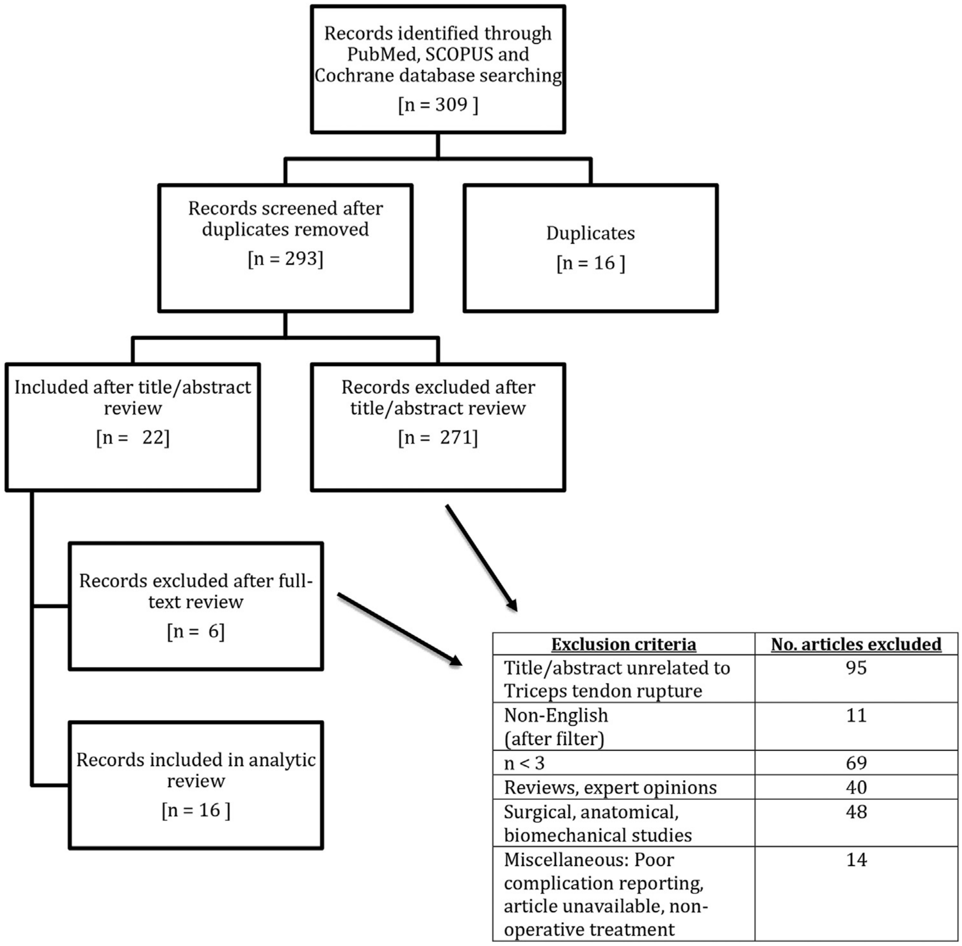
Background: Triceps tendon injury is rare and accounts for only 2% of all tendinous injuries. It typically occurs after trauma or physical strain with eccentric loading. Treatment involves surgical repair, commonly with either transosseous bone tunnels or suture anchors. Nonsurgical management is typically reserved for low-demand or high-risk patients, as this is associated with deficits in strength and functional disability. Despite several recent high-quality observational studies that have added to our understanding of outcomes after surgical repair, we are not aware of a systematic review that includes literature published after 2015. In addition, prior reviews did not compare outcomes between different surgical repair methods, particularly transosseous bone tunnel and suture anchor techniques.
Methods: This systematic review examines published literature between January 1970 and May 2021 in PubMed, Scopus, and Cochrane databases to further examine reported functional outcomes and compare those outcomes between the two surgical repair methods.
Results: Our literature search yielded 309 results, of which only 16 met inclusion criteria. At the latest follow-up, the mean Disabilities of Arm, Shoulder, and Hand score was 4, the mean Quick Disabilities of Arm, Shoulder, and Hand score was 8, the mean Mayo Elbow Performance Score was 92, the mean American Shoulder and Elbow Surgeons–Elbow score was 99, the mean modified American Shoulder and Elbow Surgeons score was 94, the mean Oxford Elbow Score was 43, and the mean isokinetic muscle strength testing was 87%. A very high percentage (95%) of patients reported being satisfied with the repair. Preinjury levels of function were achieved in 92% of patients, and 100% regained at least a score of 4 of 5 for gross muscle strength. Complications occurred in 15% of cases, of which retears accounted for 5%. Subanalysis of cases with reported repair types revealed a significantly higher overall complication rate with transosseous repairs than with suture anchor repairs (18% vs. 8%, $P = .008$) as well as a higher retear rate in the transosseous repair group (7% vs. 2%, $P = .03$).
Conclusion: Patient-reported outcome measures were favorable for both suture anchor and transosseous tunnel repair methods. Suture anchor repair showed significantly better results with regard to isokinetic strength testing, complication rates, and retear rates. Further study is needed to establish superiority of either technique and cost-efficacy. In light of the evidence supporting greater biomechanical strength and lower clinical rates of failure, surgeons may consider use of a suture anchor technique for repair of distal triceps ruptures.

Triceps tendon ruptures are extremely rare, accounting for less than 2% of all tendon injuries.[2] This injury affects men more than women at 11:1 and is associated in those with chronic elbow pain and tendinopathy.[21] Prior studies suggest an association with anabolic steroid use and systemic diseases that affect bone health, such as diabetes, rheumatoid arthritis, chronic kidney disease, and secondary hypoparathyroidism; however, data are still limited.[20,21]

Rupture is typically caused by trauma or physical strain with heavy eccentric loading, such as falling on an outstretched hand, or in sports like weight lifting.[5,20] Ruptures usually occur at the muscle bone conjoint, although intramuscular ruptures have been reported as well.[20] A clinical finding that suggests possible injury includes a palpable gap proximal to the olecranon, where the tendon would be, although swelling and inflammation may mask

*Corresponding author: Jeremy S. Somerson, MD, Department of Orthopaedic Surgery and Rehabilitation, The University of Texas Medical Branch, 2.316 Rebecca Sealy, 301 University Blvd Route 0165, Galveston, TX 77555-0165, USA.
E-mail address: jesomers@utmb.edu (J.S. Somerson).
[1] Present affiliation and address: Riverside Community Hospital, 4445 Magnolia Ave., Riverside, CA 92501, USA.

https://doi.org/10.1016/j.xrrt.2022.04.001
2666-6391/



Exclusion criteria	No. articles excluded
Title/abstract unrelated to Triceps tendon rupture	95
Non-English (after filter)	11
n < 3	69
Reviews, expert opinions	40
Surgical, anatomical, biomechanical studies	48
Miscellaneous: Poor complication reporting, article unavailable, non-operative treatment	14

Figure 1 Inclusion and exclusion process, with reasons for exclusion.

this. Another indicator is the flake sign seen on lateral elbow radiographs, signifying an avulsion fracture at the olecranon.[5]

Treatment options include nonoperative management or surgical repair, commonly with transosseous bone tunnels (TBTs) or suture anchors (SAs). Nonoperative management is associated with a deficit in extension strength and a longer recovery time and is usually only considered in patients with small partial tears, low-demand patients, or high-risk patients who cannot tolerate repair.[22] Operative treatment is indicated for complete rupture of the tendon in the majority of patients. The traditional treatment technique is with TBTs; however, the use of SA techniques has become more common in recent years. Cadaver studies have shown no significant differences between the two methods, and published clinical outcomes have been limited.[6] Dunn et al[9] conducted a systematic review including literature published through 2015 and concluded that surgical repair overall is associated with good outcomes. However, we are not aware of prior studies that specifically examine functional outcomes and compare them across surgical techniques. Given that several high-quality observational studies have been performed since the last published systematic review on this topic, we performed a systematic review to (1) examine reported functional outcomes of patients after surgical repair of triceps tendon rupture and (2) compare the reported functional outcomes of TBT and SA techniques.

Materials and methods

This study was reported following the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. Institutional review board approval was not required for this project. A systematic review was performed to include articles published between the years 1970 and May 2021 in the PubMed, Scopus, and Cochrane databases. Search terms included “triceps,” “rupture,” and “repair.” Inclusion criteria were a minimum of three patients, triceps tendon injury or rupture, surgical intervention for the injury, and reporting of outcomes. Exclusion criteria include smaller studies with fewer than 3 patients, review articles, systematic reviews, meta-analyses, biomechanical analyses/comparisons, animal/cadaveric studies, articles not written in English, articles on technique without reported outcomes, and studies not involving triceps injury and/or surgical repair of the ruptured triceps tendon. Articles generated by the search were assessed for eligibility by two independent reviewers following the inclusion and exclusion criteria. In the event of disagreement for article inclusion, the final decision was made by the senior author of the review.

The primary data point of interest was the reported functional outcomes after triceps tendon rupture repair via the TBT or SA techniques. The secondary data points include complications and complication rates. Techniques were classified as either SA or TBT. Hybrid techniques that used at least one SA in combination with

Table I
Case series: surgical volume, technique, reported outcomes, and complications.

Author	Repairs	Technique	Reported outcomes	Complications
Kokkalis et al[16]	11	Suture anchor	Pain: 8.5/10 Gross strength: 4.8/5 Mean ROM: 136 degrees (120-150) Mean loss of elbow extension: 7 degrees (0-20) Mean extension lag: 7.3 degrees (0-15) 9 of 11 patients were satisfied with the repair and were able to return to preinjury status and activities	1 case with pain over olecranon suture knot 1 wound infection with persistent moderate pain after treatment and after wound lavage and debridement
Edelman et al[10]	9	Suture anchor	Elbow extension: -3 degrees (-13 to 5) Elbow flexion: 156 degrees (148-165) 4 patients involved with workers' compensation were able to return to work 16 weeks postoperatively.	1 retear
Bava et al[4]	5	Suture anchor	ASES-E: 99 DASH: 1.4 MEPS: 96 OES Pain: 99 Function: 100 Social: 96	None
Heikenfeld et al[14]	14	Suture anchor (arthroscopic)	MEPI Pre-op: 67 6 mo post-op: 91 12 mo post-op: 97 QuickDASH Pre-op: 20.1 6 mo post-op: 7.7 12 mo post-op: 4.5 Isokinetic measurement compared to the contralateral arm Pre-op: 38.9% 12 mo post-op: 94.7%	2 cases with recurrent olecranon bursitis 1 incomplete healing with good outcomes and did not require revision surgery.
Kose et al[17]	8	Transosseous bone tunneling	Gross strength: 5/5 MEPS: 96 (85-100) Reported outcomes Excellent: 6 of 8 patients Good: 2 of 8 patients 5 degree loss of extension in 2 patients	1 ulnar entrapment requiring release and transposition 1 posterior interosseus nerve palsy after simultaneous radial head fixation
Horneff III et al[15]	56	Transosseous bone tunneling (33, 58.9%) Suture anchor (23, 41.1%)	MEPS Whole cohort: 94 $\pm$ 10 Transosseous: 93 Suture anchor: 96 No significant difference DASH Whole cohort: 4.8 $\pm$ 5 Transosseous: 3.6 Suture anchor: 6.6 Significantly different, but not clinically significant VAS pain score: Transosseous: 0.6 Suture anchor: 0.7 Reported as similar between groups Patient satisfaction: Satisfied: 53 cases (95%) Not satisfied: 3 cases (1 transosseous and 2 suture anchors) Patient would repeat surgery: Yes: 54 cases (96%). No: 2 cases (1 of each technique)	4 retears (2 transosseous bone tunneling and 2 suture anchors)
Mirzayan et al[19]	184	Transosseous bone tunneling (105) Suture anchor (73) NR (6)	Release from care: Transosseous bone tunneling: 4.3 mo Suture anchor: 3.4 mo Although there was no significant difference, infection and retear rates were increased in the transosseous bone tunnel group.	7 retears, all transosseous bone tunnel repairs 11 reoperations 1 suture anchor repair 10 transosseous bone tunnel repairs 4 wound infections, all transosseous bone tunnel repairs 3 patients with neuropraxia 2 suture anchor repairs 1 transosseous bone tunnel repair

Table I (*continued*)

Author	Repairs	Technique	Reported outcomes	Complications
Balazs et al[3]	48	NR	45 of 48 military patients returned to active duty Of the 3, 2 were discharged due to pain related to injury 11 of 45 completed their military service 37 of 45 were still currently in service at time of data collection	6 retears 1 delayed healing 1 rash 4 cases with chronic pain/weakness
Dunn et al[8]	37	Transosseous bone tunneling (9) Suture anchor (3) NR (25)	14 patients reported: DASH: 4.7 (0-15.9) MEPS: 85 (SD ±12; range, 60-100) Push-ups: 54 (SD ±26; range, 9-90) 12 were satisfied 9 patients were redeployed 97% of patients returned to service or underwent routine nonmedical leave 1 patient discharged before 2 yr due to the triceps injury	1 retear
Giannicola et al[12]	28	Transosseous bone tunneling (21) Suture anchor (7)	MEPS: 94 (60-100) QuickDASH: 10 (0-52); m-ASES: 94 (58-100) MEPI: Excellent: 21 Good: 5 Fair: 2 Gross strength: 4.64/5 5/5: 18 repairs 4/5: 10 repairs	1 re-tear 1 with 20 degrees of extension loss 1 had reaction to suture material 1 wound dehiscence 1 wound keloid
Van Riet et al[20]	23	Transosseous bone tunneling	Average loss of elbow extension: 10 degrees Average ROM of elbow flexion: 135 degrees Average ROM after primary repair: 8-138 degrees Average ROM after reconstruction: 13-133 degrees Gross strength: 5/5 or 4/5 in all patients Isokinetic strength testing 1 yr post-op compared to the contralateral arm (10 patients): 82% (range: 35%-106%) Primary repair: 92% (75%-100%) Reconstruction: 66% (35%-100%) (9) All patients reported satisfaction with repair	4 re-tears 1 transient ulnar neuropraxia
Evans et al[11]	5	Suture anchor	MEPS: 96 (range: 85-100) OES: 42.8 (max: 48, range: 34-48) ROM 3 regained full ROM 2 had 5 degrees of fixed flexion deformity	1 wound infection
Mair et al[18]	15	NR	All players requiring repair were able to return to play at least one more season of football with full ROM and no complaints of pain or weakness	2 retears
Agarwalla et al[1]	74	Transosseous bone tunneling (24, 32%) Suture anchor (19, 26%) Primary suture repair (31, 42%)	MEPS: 90 (SD ±15) QuickDASH: 7.3 (SD ±12.9) VAS pain score: 2.0 (SD ±1.8) Patients rated elbows as 84% ± 24% of normal compared with their preinjury state 71 (96%) were at least somewhat satisfied 50 (68%) had excellent satisfaction	7 reoperations 1 revision distal triceps repair
Hall et al[13]	7	Transosseous bone tunneling	Flexion arc 0°-140° with full supination and pronation in all patients Gross strength: 5/5 in all patients DASH: 1.3 (range, 0-8.3) MEPS: 99.3 (range, 95-100) Satisfaction: 4/5 (n = 1) 5/5 (n = 6) VAS: 0 in all patients 100% return to work	1 infection-related partial rerupture 1 intermittent ulnar neuropathy
Waterman et al[23]	69	Transosseous bone tunneling (30, 43%) Suture anchor (13, 19%) Primary suture repair (23, 33%)	SANE score: 91 ±15 VAS score: 1 ± 1.7 KJOC score: 85 ± 20 MEPS score 91 ± 26 QuickDASH score: 10 ± 15	8 cases with persistent pain/numbness 4 cases with tendon calcification/thickening 1 triceps adhesion 1 olecranon cyst 1 dehiscence

ROM, range of motion; *ASES-E*, American Shoulder and Elbow Surgeons-Elbow; *DASH*, Disabilities of Arm, Shoulder, and Hand; *MEPS*, Mayo Elbow Performance Score; *OES*, Oxford Elbow Score; *NR*, not reported; *MEPI*, Mayo Elbow Performance Index; *VAS*, visual analog scale; *SD*, standard deviation; *SANE*, Single Assessment Numeric Evaluation; *KJOC*, Kerlan-Jobe Orthopaedic Clinic.

Table II
Case series: average age, mean follow-up, time to surgery, radiographic evidence, and comorbidities.

Author	Average age (range)	Mean follow-up (range)	Time to surgery (range)	Radiographic evidence	Comorbidities
Kokkalis et al[16]	53 yr (34-64)	21 mo (12-40)	8 d-3 weeks	X-ray in 8 patients MRI confirmed complete rupture in all patients	N/A
Edelman et al[10]	53 yr (42-63)	Minimum 6 mo	N/A	N/A	N/A
Bava et al[4]	47 yr (35-54)	32 mo (18-49)	N/A	MRI confirmed complete ruptures	N/A
Heikenfeld et al[14]	58 yr (39-71)	N/A	N/A	MRI confirmed partial ruptures	10 patients had chronic olecranon bursitis, of which 6 had prior open bursectomy
Kose et al[17]	25 yr (16-42)	18.8 mo (12-26)	N/A	X-ray was used in all patients MRI was used for one case of chronic rupture US was used in one patient to confirm diagnosis CT was used for 3 cases to confirm associated fracture	1 with history of anabolic steroid use
Horneff III et al[15]	53 yr (19-77)	4 yr (1-11)	N/A	N/A	N/A
Mirzayan et al[19]	49 yr (15-83)	N/A	19 d (1-90)	X-ray: used in all cases 118 showed osseous flake MRI: used in 71 of 118 w/ flake sign and 47 of 66 w/o flake sign	31 had hypertension 15 cases were not recorded 13 had diabetes 11 had hyperlipidemia 11 had obesity 9 had chronic kidney disease 4 had asthma 4 had gout 2 had depression 2 had end-stage renal disease (on dialysis) 2 had hypothyroid 2 had osteoporosis 1 had alcoholism 1 had Crohn's disease 1 had dermatitis 1 had hepatitis C 1 had Parkinson's disease 1 had sarcoidosis 1 had thalassemia 1 had thrombocytopenia 3 had anabolic steroid use
Balazs et al[3]	37 yr (18-58)	26 mo (12-47)	22 d (3-278)	Unspecified imaging was used in 32 cases	13 had hypertension 5 had hyperlipidemia 6 had GERD 5 had obstructive sleep apnea 2 had mental health 2 had cardiac disease 1 had renal disease 1 had liver disease 5 had miscellaneous
Dunn et al[8]	38 ± 9 yr (19-54)	50 ± 17 mo (27-80)	N/A	MRI confirmed rupture in all cases.	8 cases with tobacco use 3 cases with steroids
Giannicola et al[12]	45 yr (14-76)	47.5 mo (12-204)	N/A	X ray in all US in 9 MRI in 18 CT in 3	7 with ipsilateral limb injury/ fracture 3 with corticosteroid use for chronic asthma, polymyalgia rheumatica, and rheumatoid arthritis. 1 had chronic renal failure.
Van Riet et al[20]	47 yr (21-69)	93 mo (7-264)	7 d	X rays: 5 patients MRI: 5 patients to confirm diagnosis	8 with prior elbow surgery
Evans et al[11]	N/A	6 mo	10 d-11 mo	X ray US MRI	N/A
Mair et al[18]	29 yr (22-36)	3 yr	N/A	MRI: 19 patients	5 with history of corticosteroid injections for olecranon bursitis prior to injury. No reported use of anabolic steroids, although one player was later suspended for steroid use.
Agarwalla et al[1]	46 yr (SD ± 11)	5.9 yr (SD ± 3.9)	4 mo (SD ± 9)	N/A	N/A
Hall et al[13]	38 yr (19-50)	4.1 yr (2.4-5.3)	54 d (10-105)	X ray MRI	1 with kidney stones and psoriasis 1 with asthma

Table II (*continued*)

Author	Average age (range)	Mean follow-up (range)	Time to surgery (range)	Radiographic evidence	Comorbidities
					1 with arthritis 1 with depression 1 with occasional smoking
Waterman et al[23]	48 yr (SD ± 12.5)	4 yr (1-10)	49 d (1-3650)	X ray MRI	N/A

MRI, magnetic resonance imaging; *N/A*, not available; *US*, ultrasound; *CT*, computed tomography; *GERD*, gastroesophageal reflux disease; *SD*, standard deviation.

Table III
Reported outcomes of case series.

Characteristic	N	Value
Patients	591	591
Repairs	593	593 (100%)
Transosseous bone tunnel repair	260	260 (44%)
Suture anchor repair	182	182 (31%)
Unspecified	151	151 (25%)
Average age	588	46 yr (range, 14-83)
Average follow-up	386	50 mo (range, 7-264)
Mean DASH	82	4.28 (range, 0-52)
Transosseous bone tunnel repair	40	3.19
Suture anchor repair	28	5.65
Unspecified	14	4.70
Mean QuickDASH	185	8.39
Transosseous bone tunnel repair	30	10.9
Suture anchor repair	27	4.26
Unspecified	102	8.04
Mean MEPS	280	92 (range, 60-100)
Transosseous bone tunnel repair	78	95
Suture anchor repair	60	93
Unspecified	116	90
Mean ASES-E	5	99
Transosseous bone tunnel repair	NR	NR
Suture anchor repair	5	99
Unspecified	NR	NR
Mean m-ASES	28	94 (range, 58-100)
Transosseous bone tunnel repair	NR	NR
Suture anchor repair	NR	NR
Unspecified	28	94.0
Mean OES	5	43 (range, 34-48)
Transosseous bone tunnel repair	NR	NR
Suture anchor repair	5	43
Unspecified	NR	NR
Mean gross motor strength	54	4.8/5
Transosseous bone tunnel repair	15	5.0/5
Suture anchor repair	11	4.8/5
Unspecified	28	4.6/5
Isokinetic muscle strength testing*	37	87%
Transosseous bone tunnel repair	23	82%
Suture anchor repair	14	95%
Unspecified	NR	NR
Patient satisfied	185	175 (95%)
Transosseous bone tunnel repair	7	7 (100%)
Suture anchor repair	11	9 (82%)
Unspecified	167	159 (95%)
Returned to preoperative function	201	185 (92%)
Transosseous bone tunnel repair	7	7 (100%)
Suture anchor repair	20	16 (80.0%)
Unspecified	174	162 (93.1%)
Complications	593	87 (15%)
Transosseous bone tunnel repair	206	38 (18%)
Suture anchor repair	153	13 (9%)
Unspecified	228	36 (16%)
Retears	593	27 (5%)
Transosseous bone tunnel repair	206	14 (7%)
Suture anchor repair	153	3 (2%)
Unspecified	228	10 (4%)

DASH, Disabilities of Arm, Shoulder, and Hand score; *QuickDASH*, Quick Disabilities of Arm, Shoulder, and Hand; *MEPS*, Mayo Elbow Performance Score; *ASES-E*, American Shoulder and Elbow Surgeons-Elbow; *NR*, not reported; *m-ASES*, modified American Shoulder Elbow Surgeon; *OES*, Oxford Elbow Score.
*Compared to the contralateral arm.

bone tunnels were considered SA techniques. This decision was based on the study by Horneff, which included hybrid techniques in their SA group.[9]

Patient demographics, surgical technique, reported functional outcomes (such as, but not limited to, strength, range of motion, return to prior function/occupation, and extremity/joint-specific functionality reporting tools), and complications were collected from each eligible study and pooled into a data sheet. Weighted averages were computed and then compared and assessed. Statistical significance was defined as $P < .05$ for all statistical analyses performed. For comparison of complication and retear rates between TBT and SA repairs, a chi-square goodness-of-fit test was used.

Results

Our search yielded 309 studies, of which only 16 met criteria (Fig. 1). A total of 591 patients and 593 repairs were included in the review (Table I). The average age of patients was 46.3 years (range, 14-83 years), and the average follow-up period was 50 months (range, 7-264 months) (Table II).

Of the cases with reported repair types, 182 were classified as SA and 260 as TBT techniques. The mean Disabilities of Arm, Shoulder, and Hand (DASH) score was 4 (TBT vs. SA, 3 vs. 6), the mean QuickDASH score was 8 (TBT vs. SA, 11 vs. 4), and the mean Mayo Elbow Performance Score (MEPS) was 92. Subanalysis showed a slightly higher MEPS for transosseous repairs[13,15,17] than for SA repairs[4,11,14,15,23] (95 vs. 93, $P = .04$). The mean American Shoulder and Elbow Surgeons−Elbow score was 99, the mean modified American Shoulder and Elbow Surgeons score was 94, the mean Oxford Elbow Score was 43, and the mean isokinetic muscle strength testing was 87% (TBT vs. SA, 82% vs. 95%) (Table III). Ninety-five percent of patients reported being satisfied with the repair, with 92% returning to preinjury levels of function and 100% regaining at least a score of 4 of 5 for gross muscle strength (Table III).

Complications occurred in 15% of cases, of which retears accounted for 5%. Subanalysis of cases with reported repair types revealed a significantly higher complication rate in TBT repairs[13,15,17,19,20,23] than in SA repairs[4,10,11,14-16,19,23] (18% vs. 8 %, $P =$ .008). Of those complications, TBT repairs had a significantly higher rate of retears than SA repairs (7% vs. 2%, $P = .03$). The SA cohort was significantly older than the TBT cohort (51 vs. 48 years, $P < .0001$). Regarding cases in which surgical technique was not specifically reported, complications occurred in 16% of repairs, of which 4% were retears.

Discussion

We identified excellent results after surgery for both TBT and SA techniques, although SA fixation showed a significantly lower rate of overall complications and rerupture. There was an overall 95% rate of patient satisfaction, and 92% were able to return to preinjury function.

Biomechanical data have shown a knotless SA fixation technique to have greater load and cycle to failure with less repair site motion than a standard TBT repair.[7] However, a prior systematic review by Dunn et al[9] noted that clinical evidence was inadequate to determine whether one technique was superior to another. More recent literature has added to our understanding of the clinical differences in outcome. This review includes 5 additional case series (358 repairs) that were not included in the review by Dunn et al (11 case series, 235 repairs).[7] Mirzayan et al[19] reviewed 184 cases of triceps repair and found a higher rate of reoperation and rerupture when a TBT repair technique was used. Our findings were similar, with significantly more complications in TBT procedures than in SA procedures (18% vs. 8%), as well as a higher retear rate (7% vs. 2%).

Prior published literature did not show substantial differences in patient-reported outcome scores between SA and TBT repair groups. Horneff et al[15] compared 33 cases of TBT repair with 23 cases of SA repair and reported the postoperative DASH score and MEPS. Although the TBT group showed a slightly better MEPS and DASH scores than the SA group, neither difference reached a level of clinical significance. Our meta-analysis showed a significantly higher MEPS for transosseous repairs[13,15,17,23] than for SA repairs[4,11,14,15,23] (95 vs. 93, $P = .04$). However, both groups fell in the "excellent" range of outcomes, and this difference does not reach a level of clinical significance.

In addition to functional outcome reporting tools, we also looked at gross and isokinetic motor strength. Elbow strength after repair was evaluated grossly on exam, and formal strength testing was done with a machine comparing it to the contralateral unaffected arm. The overall mean gross strength was 4.8 on a 5-point scale. The mean gross strength by repair technique was similar at 5.0 and 4.8 for TBT (n = 15) and SA (n = 11), respectively. However, gross strength testing results were reported in only 26 cases. Isokinetic strength was slightly more commonly reported, with 37 published cases reporting a mean of 87% of contralateral strength. Comparison of repair techniques revealed that SA repair (14 cases) had a higher percentage of isokinetic strength than TBT repair (23 cases) (95% vs. 82%, respectively). The significance of these findings is unclear, given the small sample size and variable reporting regarding arm dominance.

Patient satisfaction and ability to return to work were also examined as indirect measures of functional outcome after injury and repair. Overall, 94.6% of patients reported they were satisfied, with 92% of patients returning to work. Data by repair technique were limited. Eleven SA cases reported 81.8% patient satisfaction, while 20 SA cases reported 80% returning to preoperative function. Seven transosseous cases reported 100% satisfaction and return to work. Overall patient satisfaction and return to preoperative function are favorable and suggestive of good functionality.

This work has the inherent limitations of a systematic review and meta-analysis of observational studies. The entirety of published evidence on this topic is derived from case series; to our knowledge, no randomized controlled trials have been published. This results in a high risk of bias. We observed that our extracted data were highly variable regarding reported outcome measures, follow-up times, and case volume. Additionally, the inclusion of hybrid techniques in the SA group without separate analysis is an inherit limitation to our review, just as it was a limitation to the study by Horneff.[9] However, the experience of the 593 cases included in this review can still add to our understanding of this uncommon clinical entity.

Conclusion

Triceps tendon injuries are rarely encountered by the orthopedic surgeon, but recent publications have provided valuable data to guide clinical practice. Findings from this study showed favorable functional outcomes regardless of the repair type across several different reporting measures. Complication and retear rates were observed to be significantly higher in the TBT group than those in SA techniques. Although the MEPS for the TBT group was significantly higher at the latest follow-up, this did not reach a level of clinical significance. In light of the evidence supporting greater biomechanical strength and lower clinical rates of failure, surgeons may consider use of an SA technique for repair of distal triceps ruptures.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: Dr. Somerson reports educational support from Arthrex, Medinc of Texas, and DJO/Encore, outside the scope of this project. The other authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Agarwalla A, Gowd AK, Jan K, Liu JN, Garcia GH, Naami E, et al. Return to work following distal triceps repair. J Shoulder Elbow Surg 2021;30:906-12. https://doi.org/10.1016/j.jse.2020.07.036.
2. Anzel SH, Covey KW, Weiner AD, Lipscomb PR. Disruption of muscles and tendons; an analysis of 1, 014 cases. Surgery 1959;45:406-14.
3. Balazs GC, Brelin AM, Dworak TC, Brooks DI, Mauntel TC, Tintle SM, et al. Outcomes and complications of triceps tendon repair following acute rupture in American military personnel. Injury 2016;47:2247-51. https://doi.org/10.1016/j.injury.2016.07.061.
4. Bava ED, Barber FA, Lund ER. Clinical outcome after suture anchor repair for complete traumatic rupture of the distal triceps tendon. Arthroscopy 2012;28:1058-63. https://doi.org/10.1016/j.arthro.2011.12.016.
5. Beazley JC, Lawrence TM, Drew SJ, Modi CS. Distal biceps and triceps injuries. Open Orthop J 2017;11:1364-72. https://doi.org/10.2174/1874325001711011364.
6. Carpenter SR, Stroh DA, Melvani R, Parks BG, Camire LM, Murthi AM. Distal triceps transosseous cruciate versus suture anchor repair using equal constructs: a biomechanical comparison. J Shoulder Elbow Surg 2018;27:2052-6. https://doi.org/10.1016/j.jse.2018.05.025.
7. Clark J, Obopilwe E, Rizzi A, Komatsu DE, Singh H, Mazzocca AD, et al. Distal triceps knotless anatomic footprint repair is superior to transosseous cruciate repair: a biomechanical comparison. Arthroscopy 2014;30:1254-60. https://doi.org/10.1016/j.arthro.2014.07.005.
8. Dunn JC, Kusnezov N, Fares A, Kilcoyne K, Garcia E, Orr JD, et al. Outcomes of triceps rupture in the US military: minimum 2-year follow-up. Hand (N Y) 2019;14:197-202. https://doi.org/10.1177/1558944717745499.
9. Dunn JC, Kusnezov N, Fares A, Rubin S, Orr J, Friedman D, et al. Triceps tendon ruptures: a systematic review. Hand (N Y) 2017;12:431-8. https://doi.org/10.1177/1558944716677338.
10. Edelman D, Ilyas AM. Triceps tendon anatomic repair utilizing the "suture bridge" technique. J Hand Microsurg 2018;10:166-71. https://doi.org/10.1055/s-0038-1636729.
11. Evans OG, Lawrence TM, Shahane SA. Triceps rupture: a case series, anatomical study of the triceps footprint and description of surgical technique. Shoulder & Elbow 2013;5:65-8. https://doi.org/10.1111/j.1758-5740.2012.00218.x.
12. Giannicola G, Bullitta G, Rotini R, Murena L, Blonna D, Iapicca M, et al. Results of primary repair of distal triceps tendon ruptures in a general population: a multicentre study. Bone Joint J 2018;100-b:610-6. https://doi.org/10.1302/0301-620x.100b5.Bjj-2017-1057.R2.
13. Hall RR 3rd, Sarokhan AK, Leung NL. Clinical outcomes of low-cost, anchorless repair of the triceps tendon using a proximal knot technique. Arthrosc Sports Med Rehabil 2021;3:e535-41. https://doi.org/10.1016/j.asmr.2020.12.005.
14. Heikenfeld R, Listringhaus R, Godolias G. Endoscopic repair of tears of the superficial layer of the distal triceps tendon. Arthroscopy 2014;30:785-9. https://doi.org/10.1016/j.arthro.2014.03.005.
15. Horneff JG 3rd, Aleem A, Nicholson T, Lervick G, Murthi A, Sethi P, et al. Functional outcomes of distal triceps tendon repair comparing transosseous bone tunnels with suture anchor constructs. J Shoulder Elbow Surg 2017;26:2213-9. https://doi.org/10.1016/j.jse.2017.08.006.
16. Kokkalis ZT, Mavrogenis AF, Spyridonos S, Papagelopoulos PJ, Weiser RW, Sotereanos DG. Triceps brachii distal tendon reattachment with a double-row

technique. Orthopedics 2013;36:110-6. https://doi.org/10.3928/01477447-20130122-03.
17. Kose O, Kilicaslan OF, Guler F, Acar B, Yuksel HY. Functional outcomes and complications after surgical repair of triceps tendon rupture. Eur J Orthop Surg Traumatol 2015;25:1131-9. https://doi.org/10.1007/s00590-015-1669-3.
18. Mair SD, Isbell WM, Gill TJ, Schlegel TF, Hawkins RJ. Triceps tendon ruptures in professional football players. Am J Sports Med 2004;32:431-4. https://doi.org/10.1177/0095399703258707.
19. Mirzayan R, Acevedo DC, Sodl JF, Yian EH, Navarro RA, Anakwenze O, et al. Operative management of acute triceps tendon ruptures: review of 184 cases. Am J Sports Med 2018;46:1451-8. https://doi.org/10.1177/0363546518757426.
20. van Riet RP, Morrey BF, Ho E, O'Driscoll SW. Surgical treatment of distal triceps ruptures. J Bone Joint Surg Am 2003;85:1961-7. https://doi.org/10.2106/00004623-200310000-00015.
21. Shuttlewood K, Beazley J, Smith CD. Distal triceps injuries (including snapping triceps): a systematic review of the literature. World J Orthop 2017;8:507-13. https://doi.org/10.5312/wjo.v8.i6.507.
22. Vidal AF, Drakos MC, Allen AA. Biceps tendon and triceps tendon injuries. Clin Sports Med 2004;23:707-22. https://doi.org/10.1016/j.csm.2004.06.001. xi.
23. Waterman BR, Dean RS, Veera S, Cole BJ, Romeo AA, Wysocki RW, et al. Surgical repair of distal triceps tendon injuries: short-term to midterm clinical outcomes and risk factors for perioperative complications. Orthop J Sports Med 2019;7:2325967119839998. https://doi.org/10.1177/2325967119839998.