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Invited Review

Transtendon repair in partial articular supraspinatus tendon tear

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Abstract

Introduction: Partial thickness rotator cuff tears (PTRCTs) are common, with an incidence between 17% and 37%, and a high prevalence in throwing athletes. Different surgical procedures are suggested when partial tears involve the articular portion of the rotator cuff, including arthroscopic debridement of the tear, debridement with acromioplasty, tear completion and repair, and lately transtendon repair. This systematic review describes the transtendon repair and examines indications, contraindications, complications and clinical outcome.

Source of data: We identified clinical studies listed in the Pubmed Google Scholar, CINAHL, Cochrane Central and Embase Biomedical databases in English and Italian concerning the clinical outcomes following treatment of partial articular supraspinatus tendon tear using transtendon surgical repair.

Areas of agreement: Eighteen studies fulfilled our inclusion criteria. All were published between 2005 and 2016, three were retrospective, and 15 prospective. The total number of patients was 507 with a mean age of 50.8 years.

Areas of controversy: Tear completion and repair and transtendon repair alone produce similar results.

Growing points: Transtendon surgical repair allows to obtain good-excellent results in the treatment of partial articular supraspinatus tendon tears.

Areas timely for developing research: Further studies are needed to produce clear guidelines in the treatment of partial articular supraspinatus tendon tears.

Level of evidence: IV.

Key words: PASTA, partial articular cuff tear, supraspinatus, transtendon repair, shoulder

Introduction

Partial thickness rotator cuff tears (PTRCTs) are common, with an incidence between 17% and 37% in the general population,[1] with no substantial differences seen in patients 40–60 and over 60 (respectively, 24% and 28%),[2] and a high prevalence in overhead athletes.[3,4]

PTRCTs may involve the articular surface, bursal surface, or both surfaces of the rotator cuff (RC), with an incidence of articular side lesions (prevalence of 91–94%) approximately two to three times greater compared to the bursal side.[5–7]

Different mechanisms can lead to partial articular supraspinatus tendon avulsion (PASTA), including acute trauma, repetitive microtrauma, age-related degenerative changes to the tendon and instability with secondary impingement.[8–11]

Anatomical studies demonstrate substantial differences in the morphology of the various layers of the supraspinatus tendon.[12,13] The articular layer is characterized by poor vascularization and disorganized collagen fibres, making it more vulnerable to tensile loads,[14] and the bursal layer composed by well-organized tendon bands with greater resistance to tensile loads.[15]

Regarding the pathogenesis in throwing athletes, the repetitive eccentric traction forces to which the supraspinatus tendon is subjected during the deceleration phase through the release phase of throwing result in a twisting or traction injury.[12,16]

Repetitive contact between the articular side of the RC and the posterior-superior glenoid, commonly seen in overhead athletes, produces posterosuperior glenoid internal impingement with repetitive microtrauma on the articular cuff side.[17–19]

Furthermore, post-microtrauma anterior capsuloligamentous laxity increases the posterior displacement of the point of contact between the humerus and glenoid, resulting in greater contact between the posterosuperior labrum and the greater tuberosity of RC in the abducted and externally rotated (ABER) position.[20] Otherwise, posteroinferior shoulder contraction and fibrosis, resulting from repetitive microtrauma, produce a glenohumeral point of contact shift leading to tendon surface damage.[21]

Patients with PASTA lesions may be asymptomatic or present a pattern of pathology-related signs and symptoms.[22] Shoulder pain and nocturnal pain with disturbed sleep are very common, and often more severe than what experienced by patients with full thickness tears.[23–25]

Clinical examination includes supraspinatus specific tests such as Jobe test, impingement signs tests and 60–120° painful arc sign.[8,11,26–29]

Clinical features should be correlated with imaging studies. Ultrasound (US) is a reliable and accurate non-invasive method to examine the RC for the presence of tears but with a greater diagnostic accuracy of complete compared to partial thickness tears.[30,31]

US generally underestimates tear sizes compared with direct arthroscopic evaluation with sensitivity 0.96 and 0.84 and specificity 0.93 and 0.89 in the assessment, respectively, of full thickness and partial thickness tears.[32,33]

Magnetic resonance imaging (MRI) is excellent for the detection of full thickness RC tears, but more limited for the detection of PTRCTs and in distinguishing partial tears from tendinopathy, particularly using older low magnetic field machines.[34,35] Results in the detection of PTRCTs comparing US with MRI are similar, with sensitivities of 66.7% and 63.6%, and specificities of 93.5% and 91.7% respectively.[36]

To identify PTRCTs, magnetic resonance arthrography (MRA) is more sensitive (85.9%) and specific (96.0%), and it may be further enhanced by placing the shoulder in the ABER position, improving the detection rate of posterosuperior cuff tears.[36–38]

Arthroscopic intraoperative direct evaluation still remains the gold standard in the classification of the lesion and choice of treatment.[39,40]

Currently, there is no widely accepted classification system for partial thickness RC tears.[41]

Neer classification first was used to classify RC tears arthroscopically: it has marked limitations, and does not address partial thickness tears.[42] Ellman proposed a system based on the depth of the lesion.[43,44]

Snyder *et al.*'s classification is the most commonly used for partial RC tears; it has a moderate reliability, with a kappa coefficient of 0.512 between surgeons (Table 1).[45,46]

Conservative treatment should be considered as a first option, avoiding overhead activities, reducing pain and inflammation using nonsteroidal anti-inflammatory drugs or corticosteroid injections. Physical therapy with eccentric and plyometric exercises is employed to stretch out contracted posterior capsule and to strengthen parascapular muscles to minimize dynamic impingement secondary to scapulathoracic dyskinesia.[5,47–49]

If conservative management fails, different surgical procedure are suggested,[50] without evidenced superiority of one technique (arthroscopic debridement of the tear, debridement with acromioplasty, and RC repair with or without acromioplasty, tear completion and repair[51], and lately, transtendon procedure[8]) over the others.[48,52]

This systematic review describes the transtendon repair and evaluates the different approaches, indications, contraindications, complications and clinical outcome.

Table 1 Tendon tears classifications

Neer Classification	
Stage I	Inflammation, haemorrhage, oedema
Stage II	Tendon fibrosis
Stage III	Tendon tearing
Ellman Classification	
I	<3 mm
II	3–6 mm
III	6 mm
Snyder Classification	
Location of lesion	
A	Articular
B	Bursal
C	Complete
Arthroscopic appearance of tendon	
Grade I	Minimal superficial fraying in area smaller than 1 cm
Grade II	Fraying and failure of rotator cuff fibres smaller than 2 cm
Grade III	Fraying and fragmentation of the whole surface tendon smaller than 3 cm
Grade IV	Flap tear that encompasses more than a single tendon and is larger than 3 cm

Methods

Search strategy

In March 2017, an electronic systematic search in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Fig. 1)[53] was conducted in the online PubMed, Google Scholar, CINAHL, Cochrane Central and Embase Biomedical databases using the isolated or combined keywords PASTA lesion, partial articular cuff tear, supraspinatus, transtendon repair and shoulder with no limits regarding the year of publication. Articles were included if they reported data on clinical and functional outcomes, complications evaluation in series of patients who had undergone arthroscopic transtendon repair for partial articular supraspinatus tendon tears.

Criteria for consideration

Given our language capabilities, we considered publications written in Italian and English. Two reviewers

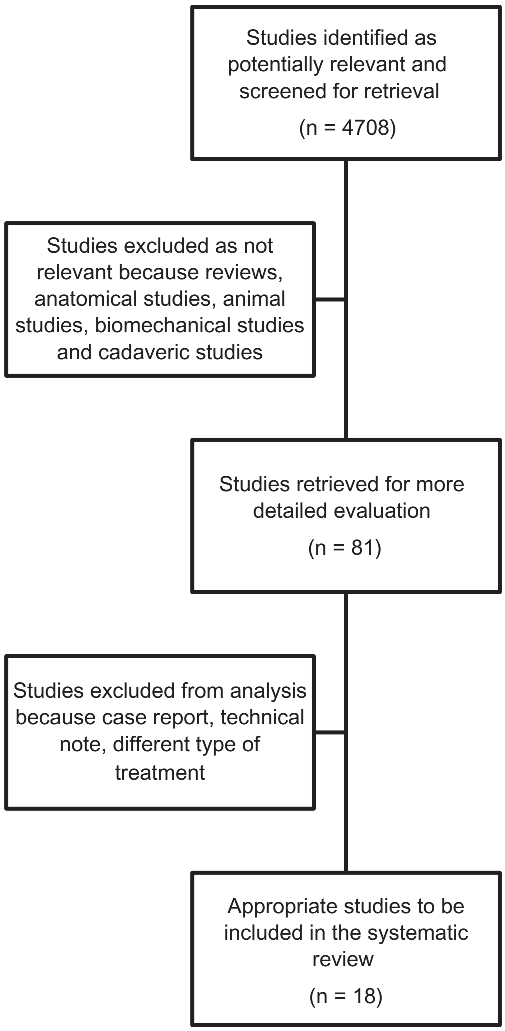

Fig. 1 Flow chart.

(M.A. and M.B.) independently reviewed the content of each abstract. Once an article was identified as likely to be included, full-text versions were obtained to evaluate the exact content of the study. The reference lists of the selected articles were then examined by hand to identify articles not identified at the electronic search. All journals were considered, and all relevant articles were retrieved. All authors reviewed and discussed the articles. Biomechanical reports, studies on animals, cadavers, case reports, literature reviews, technical notes, letters to editors, instructional course and studies focusing only on complications were excluded. A final article analysis was made by all the authors, and a fully trained orthopaedic surgeon with a special interest in shoulder surgery and sports medicine (L.O.) made the final decision in cases of doubt. Randomized controlled trials (RCTs), prospective and retrospective comparative studies and case series focusing on clinical outcomes of patients who had undergone transtendon arthroscopic repair for partial articular supraspinatus tendon tears were analysed.

Data extraction

Combining keywords and excluding non-relevant studies, 18 articles investigating patients' outcomes following transtendon arthroscopic repair for partial articular supraspinatus tendon tears were included and analysed. We did not contact the Author(s) to verify the accuracy of the data or obtain further information. Data relating to clinical features and outcomes were extracted and discussed to minimize selection bias and errors and summarized in tables using Microsoft Excel (2013 version, Microsoft Corporation, Redmond, WA, USA).

Results

Literature review

At the first electronic search, we identified 4708 relevant publications. After application of the inclusion criteria, 82 studies remained. Of these, 64 studies were excluded because they were case report, technical notes, and treatment of no-well described PTRCTs. Eighteen studies, published between 2005 and 2016, ultimately met the inclusion criteria, three were retrospective and 15 prospective (six studies were Level IV[54–59] evidence therapeutic studies). Each selected study described the surgical technique and clinical outcomes using transtendon arthroscopic repair for partial articular supraspinatus tendon tears.

Study population

The total number of patients was 507 (range 4–100) (234 males and 203 females). Four studies did not report gender.[54,60–62] The mean age was 50.8.

Using Elmann *et al.*'s classification, 10 patients had a Grade 2, 27 Grade 3, and 18 a Grade 4 tear.

One study used Snyder modified classification, and reported five patients with Grade 3 and four patients with Grade 4 tears, while nine studies did not describe the types of lesion (Table 1).

Associated lesions and procedures

A total of 142 associated lesions which underwent concomitant procedures were described in the 18 studies included in the present investigation: there were 21 acromioplasty procedures,[63,64] four distal clavicle resections (Mumford procedure),[62,64] 28 tenotomies of the long head of the biceps tendon and eight tenotomies with tenodesis,[51,55,64,65] 19 SLAP lesion repairs with anchor,[24,63,65–67] 16 debridements for partial subscapularis tears,[63] nine anchor repairs for partial subascapularis tears,[55,63,67] and one capsular release.[62]

Surgical technique

Blended anaesthesia of interscalene block and general anaesthesia were performed in all studies, with the patients in the lateral position in seven studies,[56,59,63,64,67–69] and the beach chair position in five studies.[54,55,61,62,66] An arthroscopic diagnostic examination was performed using the standard posterior portal. Other accessory portals used were a standard anterior working portal placed in the rotator interval and a lateral subacromial portal. Fraying cuff lesion margins were debrided to viable healthy tissue using a shaver through the anterior portal.[56–59,61–71] The lesion depth was then measured with a full radius shaver[58,61,63,67,69] or using calibrated probes.[66,67]

Transtendon arthroscopic repair was suggested when the tear was >50% of the tendon thickness. The tendon footprint was prepared by decortication with a burr[59,61,64,67] or with a shaver[55,62,63] or with a full-radius resector.[56] The arthroscope was then introduced into the subacromial space through a lateral portal, and an accurate bursectomy was performed to evaluate the integrity of the bursal supraspinatus tendon layer. Accurate debridement between the bursal and the articular flap side of the tendon can be performed to enhance tendon healing and avoid tension mismatch after repair. This produces a space between the two layers and increases sliding mobilization.[67]

The arthroscope was repositioned into the glenohumeral joint, and a percutaneous 18 G spinal needle was used as a guide to place one anchor at the deadman's angle of 45°. A small skin incision lateral to the border of the acromion was made to allow anchor insertion. When the cuff tear is greater than 1.5 cm, two suture anchors should be used for repair.[56,59,64,66,68,71]

The anchor was then introduced through the tendon layers into the greater tuberosity checking the correct position with direct intra-articular visualization. Titanium[55,60,64,66,69,71] or bioabsorbable[26,56,57,62,63,65,67,70] single-[61,70] or double-[55,56,59,60,62–64,66–69,71] or triple-loaded[69] suture anchors were used (Table 2).

The anchor sutures were retrieved through the anterior portal, and then shuttled through the torn edge of the partial articular RC tear. Finally, the sutures were tied in the subacromial space.

Modified surgical techniques were proposed to reduce the disadvantages of this technique.[57,61,66,69]

Tauber *et al.*[61] performed a transosseous arthroscopic repair producing two transosseous tunnels in the greater tuberosity using a cannulated curved hollow needle. The entry point of the tunnel at the footprint should be close to the lateral head of the humeral head cartilage, and the exit point should be ~1.5 cm distal to the greater tuberosity. A nitinol eyelet wire loaded with a No. 5 Fibre wire was then used to perform a mattress suture, producing a large area of tendon-to-bone contact with its two point fixation.

Using an all-inside repair technique where the sutures from all the anchors pass through just the articular layer of the RC, and a second anterior portal to retrieve the sutures tail within the intra-articular portion, the knot was buried between the intact bursal layer and the newly repaired articular one.[57]

Martinez *et al.*[66] described a double band double-pulley repair using two anchors, respectively, anteriorly at the beginning of the supraspinatus tear and through the infraspinatus. Using an angulated penetrator, they performed a medial and a lateral band of sutures on top of the RC, producing a broad contact at the tendon-to-bone interface.

Table 2 Demographic data

Study	N, M/F	Classification	Mean age (y)	Type	Follow-up (m)	Decubitus	Technique	Associate procedure	Anchors	PROM	AROM
Ide *et al.* (2005)[71]	17 (6 athletes), 14/3	n/a	42 (17–51)	PS	39 (25–57)	LD	Transtendon	n/a	Single anchor in three patients, two anchors in 14 patients	Immediately	2 w
Tauber *et al.* (2008)[61]	16, n/a	Ellman: seven patients Grade 2, nine patients Grade 3	n/a	PS	>18	BC	Transtendon modified	n/a	n/a	Immediately	6 w
Castricini *et al.* (2009)[64]	31, 16/15	Ellman: Grade II and III	53.3 (34–69)	PS	33 (26–45)	LD	Transtendon	Seven subacromial decompression One distal clavicle resection (Mumford procedure) Two tenotomy of the LHB and 6 tenotomy with tenodesis	One anchor in 26 patients and two anchors in five patients	n/a	n/a
Spencer (2010)[57]	20, 16/4	n/a	41 (18–54)	PS	29 (16–41)	n/a	Transtendon modified	n/a	3-mm polyetheretherketone anchor	2 w	4 w
Seo *et al.* (2011)[56]	24, 14/10	Patient RCTs involving more than half of the normal thickness	51 (32–70)	PS	12	LD	Transtendon	n/a	3.7-mm double-loaded Bio-Suture Tak Two suture anchors in nine patients, one suture anchor in 15 patients	Immediately	2 w
Martinez *et al.* (2012)[66]	9 active throwing athletes, 9/0	Snyder mod.: five patients Grade 3, four patients Grade 4 Ellmann: three patients Grade II, six patients Grade III	24 (19–44)	PS	12	BC	Transtendon modified	Three SLAP tears repaired	Two double-loaded titanium anchors	n/a	n/a
Ji *et al.* (2012)[69]	39, 15/24	n/a	56.2 (44–65)	PS	12	LD	Transtendon modified	Thirty-three partial biceps tear Six LHB instability	4.5-mm Twin Fix Ti	Immediately	4 w
Castagna *et al.* (2015)[60]	37, n/a	n/a	54 (21–68)	PS	>24	n/a	Transtendon	n/a	5.0-mm Fastin anchors (Mitek) double-loaded with No. 2 Orthocord (Ethicon)	n/a	4 w
Stuart *et al.* (2013)[58]	15, 11/4	Ellman: one patient Grade 3, 14 patients Grade 4	50.4 (31–68)	PS	162 (144–180)	n/a	Transtendon	Thirteen concomitant procedures		Immediately	4 w

Franceschi *et al.* (2013)[63]	32 (20 athletes), 18/14	n/a	57.3 (38–71)	PS	15.5 (7–23)	LD	Transtendon	Thirteen debridement for partial subscapularis tears Five anchor repair for partial subscapularis tears Fourteen acromioplasty Ten tenotomy of the LHB Five anchor repair for Type-II SLAP lesions	5.5-mm Bio-Corkscrew	1 w	4 w
Kim *et al.* (2013)[65]	32, 16/16	n/a	51.8 ± 13.7	PS	17.4 ± 4.2	n/a	Transtendon	Seven LHB tenotomy Three SLAP lesion repair	4.5-mm Bio-Corkscrew	n/a	4 w
Woods *et al.* (2014)[70]	8, 7/1	n/a	52.2 ± 8.7	RS	21.2 ± 9.7 (12–36)	n/a	Transtendon	n/a	5.5-mm Bio-Corkscrew	Immediately	6 w
Banerjee *et al.* (2015)[54]	4, n/a	n/a	n/a	PS	17.3 ± 6.1	BC	Transtendon	n/a			
Wang *et al.* (2015)[68]	12, 5/7	Ellman: 12 patients Grade 3	52.9 ± 13.3 (29–72)	PS	22 ± 7.3 (12–36)	LD	Transtendon	n/a	One rivet of 5-mm or two rivets of 3.5-mm	Immediately	4 w
Vinanti *et al.* (2017)[59]	100 (12 cases of isolated PASTA repair), 52/48	Ellman: 49 patients Grade 2, 51 patients Grade 3	50.4 (17–71)	RS	37 (24–50)	LD	Transtendon	n/a	4.5-mm double-loaded suture anchors for <1.5 tears and two anchors for >1.5 cm tears	10 d	6 w
Fukuta *et al.* (2015)[62]	13, n/a	n/a	n/a	PS	12	BC	Transtendon	Three resection of the distal clavicle One SLAP repair One capsular release	Bioabsorbable anchor Panalock Loop RC	Immediately	4 w
Ranalletta *et al.* (2016)[55]	80, 35/45	Ellman: Grade 3	51 ± 5.4 (33–72)	PS	62 (24–96)	BC	Transtendon	Five LHB tenotomy Two LHB tenodesis Four suture of the upper margin of the subscapularis	5.5-mm CrossFT anchor with 2 HiFi Sutures	n/a	n/a
Shin *et al.* (2016)[67]	18, 6/12	n/a	48 ± 12 (22–59)	RS	31 ± 5 (24–40)	LD	Transtendon	Three partial subscapularis tear, four type-I SLAP lesions, three type-II SLAP lesions	2.9-mm double-loaded suture anchor Juggerknot	Immediately	6 w

Ji *et al.*[69] described a transtendon arthroscopic repair with biceps tendon augmentation to increase tendon healing. They used one anchor with four sutures passing through the tissue and a biceps tendon tenodesis to the articular tear margin to fill the gap between the articular tear site and the exposed bone of the greater tuberosity.

Rehabilitation protocol

Different immobilization are used in the first postoperative weeks such as abduction shoulder brace[56,58,64,71] with zero degree of external rotation and 15° of abduction[63,67] or 20° abduction sling,[59,60] or a standard sling,[55,61,69,70] or a skull traction bandage in mild abduction.[68]

The majority of authors suggest a shoulder brace for 4 weeks.[55,58,60,63,67–69,71] Nine articles[56,58,61,62,67–71] encourage ROM exercises of the elbow, wrist and passive Codman exercises immediately to reduce inflammation and avoid shoulder stiffness, while other authors recommend to start passive exercises 1 week[55,63] after surgery.

Active assisted ROM exercise were started from 2 weeks in three studies,[55,56,71] from 4 weeks in eight studies,[57,58,60,62,63,65,68,69] and from 6 weeks in four studies[59,61,67,70] after surgery, while strengthening exercises were introduced mainly at 6 weeks.[55,58,63,70,71]

Vinanti *et al.*[59] delayed passive Codman exercises for 10 days after surgery, and strengthening exercise for 12 weeks after surgery. Spencer[57] suggested supine active assisted forward elevation and external rotation since the second postoperative week, while supine active forward elevation and internal rotation stretching were started at 6 weeks postoperatively. Furthermore, upright forward elevation with isometric strengthening was allowed at 8 weeks postoperatively. Tauber *et al.*[61] extended the first phase of Codman passive movements to 6 weeks.

The rehabilitation protocols are summarized in Table 2.

Outcome measures

Clinical and functional outcomes were evaluated using the Visual analogue scale (VAS) assessment in eight studies,[55,56,59–61,65,67,69] Data on range of motion (ROM) in eight studies,[55–57,59,63,65,67,69] Constant score in five studies,[60,63,64,66,67] University of California at Los Angeles score (UCLA) in nine studies,[55,58,59,61,62,65,68,69,71] American Shoulder and Elbow Surgeons Shoulder Score (ASES) score in eight studies,[54,56,63,65,67–70] Simple shoulder test (SST) in four studies,[54,59,69,70] Residual pain and Subjective shoulder value (SSV) in one study,[54] Short form-36 (SF-36),[58] Penn Shoulder Score (PSS) in one study[57] and Japanese Orthopaedic Association (JOA) assessment in one study.[71] Lastly, in six studies the degree of patient satisfaction was assessed.[56,58,59,61,68,70]

Details from the included articles are provided in Table 3.

Complications

Complications reported in the studies reviewed are two patients with postoperative shoulder stiffness:[69] one received intra-articular injections of corticosteroids, and the other arthroscopic capsular release and manipulations. One patient developed a Popeye sign following LHB avulsion not technique related,[69] and eight patients with shoulder stiffness[55,63] were successfully treated conservatively.

Discussion

Given their particular location and morphology, PASTA lesions present peculiar biomechanical and healing features.[72]

Conservative treatment is mandatory in the first instance, but can lead to the progression of the lesion. In 40 patients with a PASTA lesion managed conservatively, progression of the tear was reported in 80% of patients, a decreased size of the lesion in only 10% of patients, an enlargement of the tear size in 50%, and progress to full thickness cuff tear in 25% of patients.[73]

A recent MRI study showed an increased size in 23/88 (26.1%) of symptomatic partial thickness tears treated conservatively, with follow-up ranging from 6 to 100 months, a lower rate compared to full thickness tears (28/34; 82.4%).[74]

Surgery is recommended when conservative treatment fails and symptoms are present for at least 6 months.[8,43,75,76]

Different options for surgical treatment of PTRCTs have been proposed: arthroscopic or mini-open debridement with or without acromionplasty,[43,75] arthroscopic transtendon repair, arthroscopic completion of the tear followed by repair.[77,78]

Debridement of partial tears with or without acromionplasty results in satisfactory results in 87% of 98 shoulders of patients (UCLA rating scale excellent in 54% and good in 32% of the patients), while two patients developed a full thickness tear.[79]

Similarly, excellent results following arthroscopic subacromial decompression were reported, especially in patients with articular surface tears involving <50% of the tendon thickness, while significantly higher failure rates resulted for the treatment of bursal surface tears (29%).[80]

Again, Eisner *et al.* reported good clinical results in 30 patients (57%) treated with tendon debridement but with comparable results in 23 patients (43%) treated nonoperatively without statistical difference (Quick-DASH score, SANE and Quick-DASH Sports module scores 8.1 vs. 7.5, $P = 0.90$; 80.6% vs. 85.3%, $P = 0.47$; and 19.5 vs. 5.2, $P = 0.39$, respectively).[81]

Otherwise, arthroscopic acromioplasty and RC debridement in 33 patients with PTRCTs did not protect the RC from undergoing further degeneration, as shown in nine of 26 patients evaluated with US who developed a full thickness RC tear in the treated shoulder at the last follow-up.[82]

Furthermore, Weber *et al.* following two groups, 33 patients treated with debridement and acromioplasty and 33 patients with mini-open repair, showed that debridement with acromionplasty did not prevent RC tear progression (in particular, tears greater than 50% of the width of the tendon): repairing these significant partial tears may be advisable.[75]

Mazzocca *et al.* found a significant increase in strain in the remaining supraspinatus bursal fibres with a lesion between 50% and 75% on the articular side, suggesting to repair the tear when it involves over 50% of the footprint to restore the normal strain level.[83]

Deutsch evaluated the clinical outcome of 41 patients (mean age was 49 years, range 23–70 years) with greater than 50% thickness supraspinatus tears (33/41 involved the articular surface) who underwent arthroscopic completion of the lesion and repair. At a mean follow-up of 38 months (range, 24–50 months), all patients reported significant improvements of the ASES scores (from 42 to 93 points, $P < 0.001$), pain relief (from 6.5 to 0.8 points, $P < 0.001$), and 98% were satisfied with their outcome.[77]

Sixty patients underwent arthroscopic completion and repair of Ellman Grade 3 partial thickness tears of the supraspinatus, with an improvement in the ASES score from 46.9 to 85.1 in 20 partial articular tendon tears, in the Constant scores from 54.3 to 79.4, and in the visual analogue scale scores from 5.1 to 1.2.[78]

Huberty *et al.* in 489 consecutive arthroscopic RC repairs found that 24 patients (4.9%) developed postoperative stiffness. They included PASTA lesions in the group of lesions in which tendon repair could be a risk factor to develop postoperative stiffness.[84]

Snyder *et al.*,[5] as well as Burkhart and Lo,[85] first described transtendon arthroscopic repair technique for partial thickness articular tears. The transtendon technique preserves the lateral bursal-side layer intact, and restores the anatomy of the footprint, returning the avulsed tendon part to its original insertion and avoiding excision of normal tendon tissue to enhance healing. This anatomical restoration prevents length–tension mismatch that may result from advancing the RC too far laterally.[5,85]

Transtendon repair decreases glenohumeral and subacromial contact pressures reducing secondary subacromial and internal impingements and preserve the progression to full thickness RC tear.[86]

In Ranalletta *et al.* study, 92.5% good or excellent results (24 excellent, 50 good) and 7.5% (six patients) fair results were reported in the subjective evaluations of 80 patients with Elmann Grade 3 tears (35 male and 45 female, average age 51 ± 5.4 years) using this technique.[55]

Again, Castricini *et al.* in 31 patients (16 male and 15 female, average age 53.3 years) with Elmann Grade 2 and 3 lesions obtained an improvement of the Constant score from 44.4 to 91.6 (mean follow-up: 33 months) and a return to work in ~3.5 months.[64]

Table 3 Clinical results

Study	Follow-up evaluation	Results	Satisfied/*N*	Complication
Ide *et al.* (2005)[71]	UCLA, JOA assessment	UCLA: 17.3 (preop), 32.9 (postop) $P < 0.01$ JOA assessment: 68.4 (preop), 94.8 (postop) $P < 0.01$	n/a	n/a
Tauber *et al.* (2008)[61]	UCLA, VAS	VAS: 7.9 (preop), 1.2 (18 m) ASES: 15.08 (preop), 32.8 (18 m)	15/16	n/a
Castricini *et al.* (2009)[64]	Dynamometric strength test, constant	Constant: 44.4 (preop), 91.6 (postop) $P < 0.01$ Return to working: ~3.5 months	n/a	n/a
Spencer (2010)[57]	PSS, ROM	PSS: preop: 74 (56–84), postop: 92 (86–99) ROM: FF: 169 (159–176) ER1: 61 (52–69) ER2: 89 (82–94) IR: 48 (36–60)	n/a	n/a
Seo *et al.* (2011)[56]	ASES, VAS, strenght, ROM	VAS: 6.6 ± 1.1 (preop), 2 ± 0.7 (3 m), 0.6 ± 0.7 (18 m) ASES: 38 ± 13 (preop), 63 ± 5.8 (3 m),63 ± 5 (12 m) ROM: FF strength: 26 ± 7 Nm (preop), 41 ± 5 Nm (1 y) AB strength: 23 ± 3 Nm (preop), 33 ± 4 Nm (1 y) ER strength: 9 ± 3 Nm (preop), 15 ± 3 Nm (1 y) IR strenght: 23 ± 3 Nm (preop), 33 ± 4 Nm (1 y) No significant difference between affected and unaffected shoulders	22/24	n/a
Martinez *et al.* (2012)[66]	Constant	Constant score: 72 (preop), 90(6 m), 99(12 m)	n/a	n/a
Ji *et al.* (2012)[69]	SST, VAS, ASES, UCLA, ROM	VAS: 5.8 ± 2.1 (preop), 1.6 ± 1.3 (postop) $P < 0.001$ UCLA: 18.4 ± 4.4 (preop), 31.3 ± 2.5 (postop) $P < 0.001$ ASES: 52.4 ± 16.7 (preop), 86.6 ± 6.7 (postop) $P < 0.001$ SST: 6.2 ± 2.4 (preop), 9.6 ± 2.0 (postop) $P < 0.001$ ROM: FF: 146.2 ± 19.3 (preop), 161.8 ± 16.8 (postop) $P < 0.001$ AB: 142.8 ± 24.1 (preop), 162.6 ± 18.3 (postop) $P < 0.001$ ER: 37.4 ± 25.1 (preop), 37.3 ± 21.8 (postop) $P = 0.679$ IR: L1 (preop), T12 (postop) $P = 0.748$	n/a	Two shoulder stifness, one positive Popeye sign due to avulsion of LHB
Castagna *et al.* (2015)[60]	Constant, VAS	Constant score improved by a mean value of 25.1 ± 5.8 VAS score improved by a mean value of 3.4 ± 1.2	n/a	n/a
Stuart *et al.* (2013)[58]	UCLA, SF-36	UCLA: 17.9 (preop), 33.4 (early postop), 32.5 (late postop) Return to preinjury activity level: 13 patients SF-36: Significant improvements in physical functioning, role-physical, and bodily pain	15/15	n/a

Franceschi *et al.* (2013)[63]	Constant, ASES, ROM	ASES: 45.6 ± 8.1 (preop), 91 ± 6.6 (final FU) $P < 0.0001$ Constant: 48 ± 8.2 (preop), 92 ± 7.1 (final FU) $P < 0.0001$ ROM: ER: 45.6 ± 14.5 (preop), 59.8 ± 9.6 (final FU) FF: 132.8 ± 13 (preop), 171 ± 10.4 (final FU) IR a level between L3-S1 (preop); 23 patients T8, seven patients T9, two patients T10 (final FU) Athletes: 15 patients return to preinjury level, five patients not returned to the same level of sport	n/a	Three adhesive capsulitis
Kim *et al.* (2013)[65]	VAS, ASES, UCLA, ROM	VAS: 6.1 ± 1.9 (preop), 2.6 ± 1.9 (final FU) $P < 0.001$ UCLA: 19.1 ± 5.4 (preop), 35.7 ± 8.5 (final FU) $P < 0.001$ ASES: 45.2 ± 16 (preop), 79 ± 15.8 (final FU) $P < 0.001$ Constant: 58 ± 19.6 (preop), 78.1 ± 12.9 (final FU) $P < 0.001$ ROM: FF 140 ± 36.6 (preop), 163 ± 25.2 (final FU) $P < 0.001$ ABD 115 ± 53.9 (preop), 153 ± 37.1 (final FU) $P < 0.001$	n/a	n/a
Woods *et al.* (2014)[70]	ASES, SST	ASES: 42.7 ± 17.5 (preop), 86.9 ± 25.2 (postop) SST: 4.6 ± 3.2 (preop), 10.1 ± 3.8 (postop)	7/8	n/a
Banerjee *et al.* (2015)[54]	ASES, SST, SSV, Residual pain (%)	ASES: 92.9 ± 8.4 (postop) SST: 11.4 ± 1.4 (postop) SSV: 90 ± 14.1 (postop) Residual pain (%): 7.5 ± 9.6 (postop)	n/a	n/a
Wang *et al.* (2015)[68]	ASES, UCLA, Jobe test, Neer sign, anti-resistence moviments	ASES: 49.8 ± 9.8 (preop), 89.7 ± 5.6 (postop) UCLA: 17.3 ± 3.3 (preop), 30.4 ± 3.2 (postop)	11/12(91.7%)	n/a
Vinanti *et al.* (2017)[59]	SST, UCLA, VAS, ROM	UCLA: 15.35 ± 4.32 (preop), 33.16 ± 3.18 (postop) $P < 0.001$ SST: 5.38 ± 2.81 (preop), 11.37 ± 1.29 (postop) $P < 0.001$ VAS: 6.73 ± 2.38 (preop), 0.72 ± 1.33 (postop) $P < 0.001$ ROM: FF: 155° ± 13° (preop), 172° ± 8° (postop) ER: 53° ± 12° (preop) 82° ± 14° (postop) IR: 43° ± 13° (preop) 65° ± 9° (postop)	98/100	n/a
Fukuta *et al.* (2015)[62]	UCLA	UCLA: 16.5 (preop), 32.3 (1 year)	n/a	n/a
Ranalletta *et al.* (2016)[55]	ROM, UCLA, VAS, subjective result	ASES: 44.6 ± 12 (preop), 76.1 ± 1 (postop) $P < 0.001$ UCLA: 13.6 ± 3 (preop), 31.5 ± 6 (postop) $P < 0.001$ VAS: 6.3 ± 1 (preop), 1.3 ± 1 (postop) $P < 0.001$ ROM: statistically significant improvement Subjective evaluation: 92.5% good or excellent results (24 excellent, 50 good) and 7.5% (6) fair results	n/a	Five adhesive capsulitis

Continued

Table 3 *Continued*

Study	Follow-up evaluation	Results	Satisfied/N	Complication
Shin *et al.* (2016)[67]	Constant, ASES, VAS, ROM	VAS: 4.9 ± 2.6 (preop), 0.6 ± 0.7 (final FU) $P < 0.001$ ASES: 54 ± 10.3 (preop), 92.6 ± 8 (final FU) $P < 0.001$ Constant: 61.2 ± 8.5 (preop), 88 ± 5.3 (final FU) $P < 0.001$ ROM: FF: 156.8 ± 26.1 (preop), 172 ± 14.3 (final FU) $P = 0.545$ ER: 55.8 ± 27.4 (preop), 68.5 ± 17.1 (final FU) $P = 0.038$ IR: L3 (preop), L1 (final FU) $P = 0.001$	n/a	n/a

In active throwing athletes, transtendon surgical repair produces successful results. Martinez *et al.* evaluated nine patients (Ellman classification: three Grade II and six Grade III), and reported a Constant score improvement from 72 to 99 (12 months follow-up) without complication.[66]

Similarly, of the 20 athletic patients evaluated by Franceschi *et al.*, 15 returned to preinjury level and five did not return to the same level of sport. The average ASES score and Constant score at the final follow-up were respectively 91 ± 6.6 ($P < 0.0001$) and 92 ± 7.1 ($P < 0.0001$).[63]

A negative feature of the transtendon repair is the necessity to pass the anchor directly through the tendon. The diameter of the anchor ranges between 3.7 and 5.5 mm, and can cause damage to the injured tendon. This could be reduced performing a transosseous suture with a curved hollow needle (2.5 mm of diameter) that increases the tendon-to-bone contact, with a more regular distribution of the pressure onto the tendon and tendon healing.[61]

Woods *et al.*, evaluating eight patients treated with the transtendon repair technique, showed in seven patients full thickness defects through the rotator-cuff repair site on MRA at 12 months of follow-up. They conclude that the failure of the tendon occurred initially at the medial mattress sutures which absorbed the majority of the load during early rehabilitation. They suggest not to perform this technique when the tears involve more than 50% of the tendon and when the integrity of the remaining intact tendon is compromised.[70]

Furthermore, tendon repair decreases anterior translation and external rotation, and changes the relationship between the humeral head and the glenoid, causing overtightening of the bursal portion of the cuff, resulting in shoulder stiffness.[86]

Spencer proposed an all-inside transtendon repair, in which the suture is placed only in the articular damaged layer of the tendon, without passing the suture through the bursal layer and tying it down reporting good clinical results without postoperative stiffness.[57]

Transtendon repair is not recommended for high-grade partial articular tears with poor quality of tendon substance or substantial thinning, because this technique cannot restore the normal thickness of the repaired tendon.[69]

It is still debated whether partial tears should be managed with arthroscopic conversion to a full thickness tear followed by repair[75,77] to stimulate healing, similar to an acute full thickness tear.[87]

Sun *et al.*[88] showed no significant differences between these techniques regarding clinical outcomes with ASES scores, but they found a significantly lower re-tear rate and superior outcomes in the re-tear rate using transtendon repair.

Castagna *et al.*[60] compared the transtendon repair technique with completion of the tear followed by repair without statistically significant differences between the two techniques, both providing good results in terms of functional outcomes and pain.

A biomechanical study comparing the two techniques support that transtendon repair was biomechanically stronger and produced significantly less gapping during axial cyclic loading of the supraspinatus tendon.[89]

Nevertheless, it should be kept in mind that patients undergoing transtendon repair can show more pain, slower recovery and a tendency to develop greater stiffness compared to patients who underwent to conversion of the tear to a full tear followed by repair.[22,88,90]

Conclusion

Surgical repair of articular partial thickness supraspinatus tears is recommended when the tear involves over 50% of the supraspinatus footprint and conservative management has failed.

The present systematic review showed good and excellent results using arthroscopic transtendon surgical repair with low complication rates. However, there are at present no studies which demonstrate superiority of transtendinous repair over tear completion and repair. Randomized controlled trials are needed to clarify which technique offers better results in the treatment of PASTA lesions.

Conflict of interest statement

The authors have no potential conflicts of interest.

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