Archives of Orthopaedic and Trauma Surgery
https://doi.org/10.1007/s00402-020-03387-6

ARTHROSCOPY AND SPORTS MEDICINE

Arthroscopic repair of partial-thickness articular surface rotator cuff tears: single-row transtendon technique versus double-row suture bridge (transosseous equivalent) fixation: results from a prospective randomized study

Manuel Zafra[1] · Pilar Uceda[1,4] · Francisco Muñoz-Luna[2] · Rafael C. Muñoz-López[1] · Pilar Font[3]

Received: 17 July 2019

Abstract

Background The purpose of this prospective study was to compare the clinical and structural findings following the arthroscopic repair of partial-thickness (exceeding 50%) articular-sided rotator cuff tears using either a single-row or a double-row suture bridge fixation.

Materials and methods Fifty patients were included in this study. The patients were randomly placed into two groups: 25 underwent the single-row (Group I) and 25 a double-row suture bridge fixation (Group II). The clinical outcomes were assessed using ASES and Constant shoulder scores, both preoperatively and at the end of follow-up. The pain level was evaluated using the visual analogue scale (VAS), preoperatively, at 6 months and at the end of follow-up. All patients underwent preoperative MRI to identify the rotator cuff tear, and postoperatively at 12 months to evaluate tendon integrity.

Results The average follow-up was 32.5 months. The mean ASES scores increased from 35.9 to 96.7 in Group I and from 35.3 to 93.4 in Group II; the mean Constant shoulder scores increased from 55.6 to 97.8 in Group I and from 57.5 to 97.3 in Group II. There were no significant differences between the two groups. The average preoperative pain level decreased from 7.4 to 3 at 6 months and to 0.4 at the end of the Group I; and from 7.6 to 3 at 6 months and 0.8 in Group II. There was no significant difference between the two groups. At 12 months, the MRI assessments showed two retears in Group I (8%) and one retear in Group II (4%).

Conclusion Arthroscopic repair of partial-thickness articular rotator cuff tears that exceed 50% of tendon thickness with a single-row transtendon repair or double-row suture bridge provides functional improvement and pain relief regardless of the repair technique used. There were no differences in clinical results between both techniques.

Level of evidence Level II; prospective comparative study.

Keywords Partial rotator cuff tears · Single row · Double row · Arthroscopic magnetic resonance imaging

✉ Pilar Uceda
ucedasan@gmail.com

Manuel Zafra
manuelmazago@gmail.com

Francisco Muñoz-Luna
paco1962@gmail.com

Rafael C. Muñoz-López
rcml@hotmail.com

Pilar Font
fougp@hotmail.com

[1] Hospital Quirón, Instituto de Traumatología, Avda. del Aeropuerto, 14005 Córdoba, Spain

[2] Reina Sofía University Hospital, Avda. Menéndez Pidal, 14004 Córdoba, Spain

[3] IMIBIC, Universidad de Córdoba, Córdoba, Spain

[4] Isla Hierro St Number 14, 14011 Córdoba, Spain

Published online: 13 March 2020

Introduction

Rotator cuff tears are the most common cause of shoulder pain in middle-aged patients. Knowledge regarding partial rotator cuff tears is increasing due to greater life expectancy, improved imaging techniques, assuming limited diagnostic accuracy of magnetic resonance imaging (MRI) [1] and advances in arthroscopic procedures. Partial rotator cuff tears can occur on the bursal side, inside the tendon or on the articular side [2]. Tears on the articular side are two to three times more frequent than lesions on the bursal side [3, 4]. With regard to the treatment of symptomatic partial-thickness rotator cuff tears, there is no consensus, especially for tears on the articular side.

Conservative treatment can improve symptomatology and patient satisfaction [5]. However, it has been shown that partial-thickness tears do not have the potential for natural regeneration and can progress to full-thickness tears [3, 6–8].

In general, the surgical repair of partial-thickness rotator cuff tears is recommended when they extend to more than 50% of tendon thickness, although this decision is dependent on other factors such as age, sports activity and the experience of the surgeon [9]. For the surgical treatment of partial-thickness articular-sided rotator cuff tears, two repair techniques are normally used. Some prefer to convert the tear to full thickness, followed by repair using a traditional method [10, 11]. However, others advocate the transtendon repair technique to avoid sacrificing the intact bursal side of the rotator cuff tendon and to restore the cuff footprint [12, 13]. The comparison between transtendon repair and completion repair arthroscopic in patients with a partial-thickness articular-sided symptomatic rotator cuff tear demonstrated both functional and pain improvements regardless of the repair technique used [6, 14, 15]. Repair following conversion to full tears did show lower postoperative morbidity, tendon integrity being the main concern after repair [14]. On the other hand, the transtendon repair technique provided greater tendon integrity but slower functional recovery [14].

The objective of our study is to compare prospectively the clinical outcomes, the regeneration capacity and tendon integrity of the arthroscopic single-row transtendon repair versus the double-row suture bridge fixation in patients with symptomatic partial-thickness articular-sided rotator cuff tears. The working hypothesis is that the arthroscopic double-row suture bridge would provide a better clinical and functional outcome and improved tendon repair, objectively determined by magnetic resonance imaging (MRI).

Materials and methods

Fifty patients were included in this study, each had undergone arthroscopic repair for a partial-thickness articular-sided rotator cuff tear between January 2014 and March 2017. The partial-thickness articular-sided rotator cuff tears were preoperatively diagnosed by magnetic resonance imaging (MRI) (Fig. 1) and the tear was confirmed at the time of the surgery. The indication for inclusion was a tear exceeding 50% of the tendon's thickness. All patients had been treated in a conservative manner for at least 3 months prior to surgery. The following exclusion criteria were applied: patients with subscapularis tears or labral tears, being in receipt of worker's compensation and patients who had had previous surgery on the shoulder.

The power analysis was performed by an independent statistician using the GRANMO program. Accepting an alpha risk of 0.05 and a beta risk of 0.2 in a bilateral contrast, 25 patients in each group were required to detect a difference equal to or greater than 10 points on the ASES scale, assuming that the standard deviation is 12. A loss rate of 15% was estimated. This was based on the mean and standard deviation of the ASES scores according to other authors [14]. Arthroscopic treatment for partial intra-articular ruptures was performed in 89 patients during the study period. Thirty-nine patients were excluded because they did not meet the inclusion criteria.

The 50 patients who met the inclusion criteria were assigned according to a table of random numbers to one of two groups depending on the surgical repair technique—25 underwent the arthroscopic single-row rotator cuff repair technique (Group I) and 25 underwent the arthroscopic

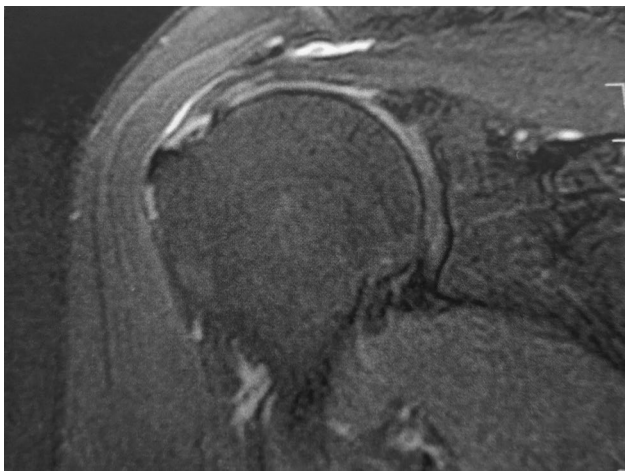

Fig. 1 A preoperative coronal T-1 magnetic resonance imaging of a right shoulder showing a partial-thickness articular tear of the supraspinatus tendon exceeding 50%

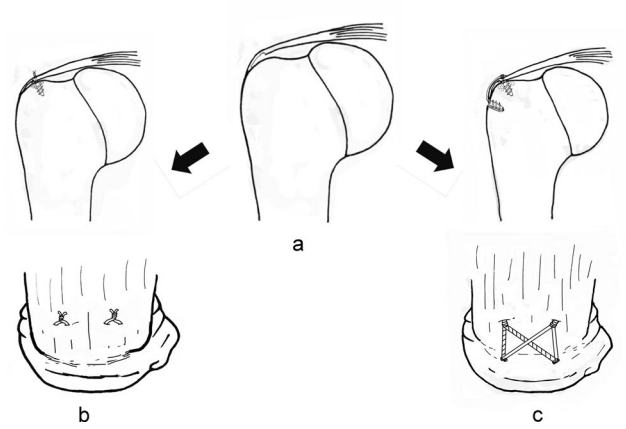

Fig. 2 Drawings showing the two techniques used in the arthroscopic transtendon repair of a partial-thickness articular rotator cuff tear. **a** A partial-thickness articular rotator cuff tear exceeding 50%. **b** Final configuration of the arthroscopic repair technique performed in Group I (a single-row technique). **c** Final configuration of the arthroscopic repair technique performed in Group II (a double-row suture bridge fixation)

Table 1 Patient's demographic date

	Group I Single row	Group II Double row	*P* value
Men/women	11/14	13/12	0.57
Dominant/nondominant	16/9	18/7	0.54
Age (years)	50.9 ± 8.6	54.1 ± 7	0.07
Symptom duration (months)	11.6 ± 5.5	12.1 ± 4.6	0.51
Trauma history	1	2	> 0.99
Steroid injection before surgery	12	14	0.73
Rehabilitation before surgery	20	19	0.82

rotator cuff repair with a double-row suture bridge fixation (Group II)—(Fig. 2). All the surgeries were performed by the same surgeon. The study was approved by the local ethics committee (No. 235/2014). Both verbal and written informed consent were obtained by all participants.

In total, there were 24 men (11 in Group I and 13 in Group II) and 26 women (14 in Group I and 12 in Group II). Findings regarding demographic data are summarized in Table 1. No difference was observed between the data of the two groups.

All patients followed the same postoperative rehabilitation protocol. A shoulder brace was applied postoperatively to all patients for 3 weeks. Passive range-of-shoulder motion exercise was started by the physiotherapist at 3 weeks. Active assisted range-of-shoulder motion exercises began at 6 weeks and lasted until 3 months. The clinical outcomes were assessed using ASES and Constant shoulder scores, both preoperatively and at the end of follow-up. The pain level was evaluated using the visual analogue scale (VAS), preoperatively, at 6 months and at the end of follow-up: a score of zero indicated no pain and ten indicated the worst possible pain.

All patients were asked to assess the subjective outcomes of the intervention in terms of being excellent, good, fair or poor. All patients underwent MRI preoperatively to identify the partial-thickness articular-sided rotator cuff tear and postoperatively at 12 months to evaluate tendon integrity. Tendon integrity or retear was assessed by an independent musculoskeletal radiologist using MRI.

Statistical method

A descriptive study of the variables was carried out calculating the absolute and relative frequencies for the qualitative variables and the means and typical deviation for the quantitative variables. To compare Group I and II with respect to epidemiological data, the Mann–Whitney *U* test was used to analyse continuous variables and the χ^2 test and Fisher's exact test were used to analyse dichotomous variables. A mixed ANOVA test was performed with the Sidak adjustment to check the quantitative variables before and after the surgical intervention according to the technique used. All of the contrasts were considered significant when $p < 0.05$. The data were processed and analysed using the SPSS (IBM) v.25 program.

Surgical technique

All patients received preoperative antibiotic prophylaxis and underwent an interscalene block. After inducing general anaesthesia, patients were placed in the lateral decubitus position. Using a standard posterior portal and with an anterior work portal placed in the rotator interval, the intra-articular pathologies were identified before the rotator cuff repair procedure. Frayed partial-thickness articular-sided rotator cuffs were debrided to expose the footprint and determine the tear and the tendon's medial retraction. The depth of the tear was measured using a calibrated arthroscopic probe with a 4 mm tip and a 4.5 mm-wide full radius shaver. Tears of more than 6 mm tendon thickness (more than 50%) were included in the study (Fig. 3). The arthroscope was transferred to the subacromial space and a bursectomy was performed via a lateral portal. Only in cases where there was a large sharp spur was an acromioplasty performed. The arthroscope was introduced into the glenohumeral joint through the posterior portal and the partial-thickness articular-sided rotator cuff tears were observed. After the decortication of the footprints, the tear was measured in its anteroposterior dimension; if the tear was less than 1.5 cm, we inserted an intra-articular anchor. However, if the tear was greater than 1.5 cm, we used two intra-articular anchors. To restore the cuff footprint correctly, it is essential to place

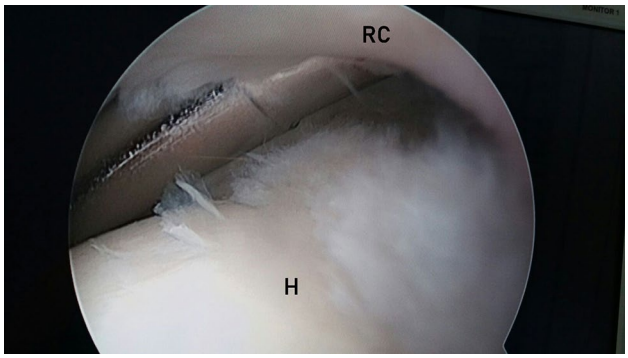

Fig. 3 Arthroscopic view of a right shoulder with the patient in the lateral decubitus position and from the posterior portal: the extent and depth of the tear can be appreciated using a radius shaver from the anterior portal. If the tip of the shaver is fully inserted into the defect, the depth of the tear is considered to be more than 50% of tendon thickness. *RC* rotator cuff, *H* humeral head

the anchors in the medial margin of the footprint, just lateral to the joint surface.

For the single-row repair (Group I), a guide (the HEALIX TRANSTEND Implant System. Depuy, Mitek) was introduced and placed adjacent to the lateral zone of the acromion through the musculotendinous junction of the rotator cuff towards the footprint with an inclination of 40° or less to allow the anchor (HEALIX TRANSTEND 3.4 mm; DePuy, Mitek) to be placed. If the cuff tear was greater than 1.5 cm (eight cases), a second anchor was inserted in a similar way approximately 1 cm posterior to the first (Fig. 4). A 14 G Abbocath catheter was inserted percutaneously into the free shaft of the torn tendon. Then, a polypropylene monofilament 0 was passed through the Abbocath and retrieved through the anterior portal. Following the withdrawal of the Abbocath, the intra-articular polypropylene end and the suture anchor end was pulled out via the anterior portal and knotted; and the other end of the polypropylene monofilament suture, outside the lateral aspect of the acromion, was pulled out. In this way, one suture limb of the suture anchor was passed through the healthy portion of the rotator cuff. The same procedure was repeated for the remaining suture limbs. The arthroscope was then positioned in the subacromial space, and via the lateral portal the sutures were tied on the bursal side of the cuff. The arthroscope was repositioned within the glenohumeral joint and the final repair was inspected.

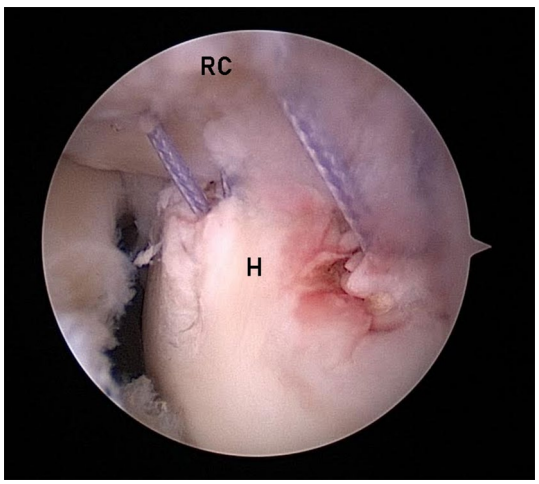

Fig. 4 Intra-articular image from the posterior portal of a right shoulder in the lateral decubitus position showing an intra-articular tear of more than 1.5 cm in its anteroposterior dimension with two anchors. The four suture limbs were passed through the healthy portion of the partially torn rotator cuff via different percutaneous Abbocaths. *RC* rotator cuff, *H* humeral head

For the double-row repair (Group II), the same anterior procedure was performed. In this group we found six tears greater than 1.5 cm. For the lateral row, after knotting, the medial anchor sutures were fixed with a lateral row anchor (HEALIX ADVANCE Knotless 4.75 mm. DePuy, Mitek) using the suture bridge technique. For the two anchors, we retrieved one suture from the anterior anchor and one from the posterior anchor through the lateral cannula. The two sutures were placed into the lateral anchor (Fig. 5).

We found one case of tendinitis of the long portion of the biceps in Group I and two cases in Group II; these were treated arthroscopically by intra-articular tenotomy and tension slide tenodesis. We performed acromioplasties on 19 patients in Group I and 18 patients in Group II.

The average follow-up duration was 32.5 months (range, 24–39 months), 32 months in Group I and 33 in Group II.

The average preoperative pain level decreased from 7.4+/1.5 to 3 ± 1 at 6 months ($p < 0.001$) and to 0.4 ± 0.6 at the end of the follow-up ($p < 0.001$) in the Group I; and from 7.6 ± 1.5 preoperatively to 3 ± 1.5 at 6 months ($p < 0.001$) and 0.8 ± 0.9($p < 0.001$) in Group II (Table 2).

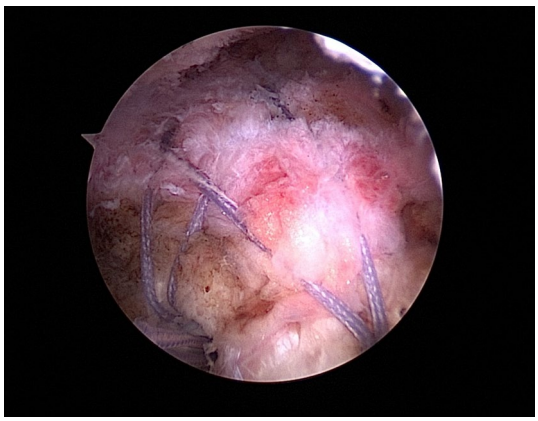

Fig. 5 Subacromial view of the final result from the lateral portal following tying using the double-row suture bridge fixation technique with two anchors

Table 2. Comparison of clinical outcomes based on the repair technique

	Preop Group I	Preop Group II	End follow-up Group I	End follow-up Group II	*P* value End follow-up Group I/Group II
Pain score (VAS)	7.4 ± 1.5	7.6 ± 1.5	0.4 ± 0.6	0.8 ± 0.9	$P = 0.07$
ASES score	35.9 ± 15.9	35.3 ± 14.6	96.7 ± 5	93.4 ± 6.9	$P = 0.06$
Constant score	55.6 ± 13.2	57.5 ± 13.2	97.8 ± 3.1	97.3 ± 3	$P = 0.5$

Preop preoperatively, *VAS* visual analogue scale, *ASES Score* American Shoulder and Elbow Surgeons Score

There were no significant differences in the results of the pain between the two groups at 6 months ($p = 0.82$) and the end of the follow-up ($p = 0.07$).

The functional results were significantly better in both groups after arthroscopic repair. The mean ASES scores increased from 35.9+/15.9 preoperatively to 96.7 ± 5 at the end of the follow-up in Group I ($p < 0.001$) and from 35.3 ± 14.6 to 93.4 ± 6.9 in Group II ($p < 0.001$). There were no significant differences in the results between the two groups at the end of the follow-up ($p = 0.06$). The mean Constant shoulder scores increased from 55.6 ± 13.2 to 97.8 ± 3.1 in Group I ($p < 0.001$) and from 57.5 ± 13.2 to 97.3 ± 3 in Group II ($p < 0.001$). Again, there were no significant differences in the results between the two groups ($p = 0.5$). In both groups, five of the patients (10%) were satisfied (two patients in Group I and three in Group II) with the surgery and 45 (90%) were very satisfied (23 patients in Group I and 22 in Group II). Postoperative adhesive capsulitis developed in one patient in Group I and two patients in Group II; they were treated with oral corticosteroids and by intensified rehabilitation therapy.

At 12 months after surgery, the MRI assessments showed two tendons retears repaired in Group I (8%) and one retear repaired in Group II (4%) (Fig. 6).

Discussion

The study shows that arthroscopic repair of partial-thickness articular-sided rotator cuff tears provides satisfactory functional improvement and pain relief regardless of the repair technique.

Partial-thickness articular-sided rotator cuff tears can be repaired after converting them to a complete tear [6, 11, 15]. Deutssh [11] advocates this because it allows for better fixation and potential tendon integrity.

Advances in arthroscopic surgical techniques allow the repair of partial tears without completing the tear. The transtendon repair technique makes it possible to anatomically restore the medial area of the footprint while preserving the bursal side of the cuff [16, 17]. Castagna et al. [18] also advocated transtendon repair and attributed their good results to decreased tendon retraction and the extensive exposure of the footprint.

Cadaver studies have shown that preserving the rotator cuff tendon intact provides better biomechanical properties than repair following a complete tear [19, 20].

Several transtendon repair techniques have been published in the literature for partial-thickness articular side rotator cuff tears. Lyons et al. [21] published a technique—to alter the debridement surface of the rotator cuff tear and

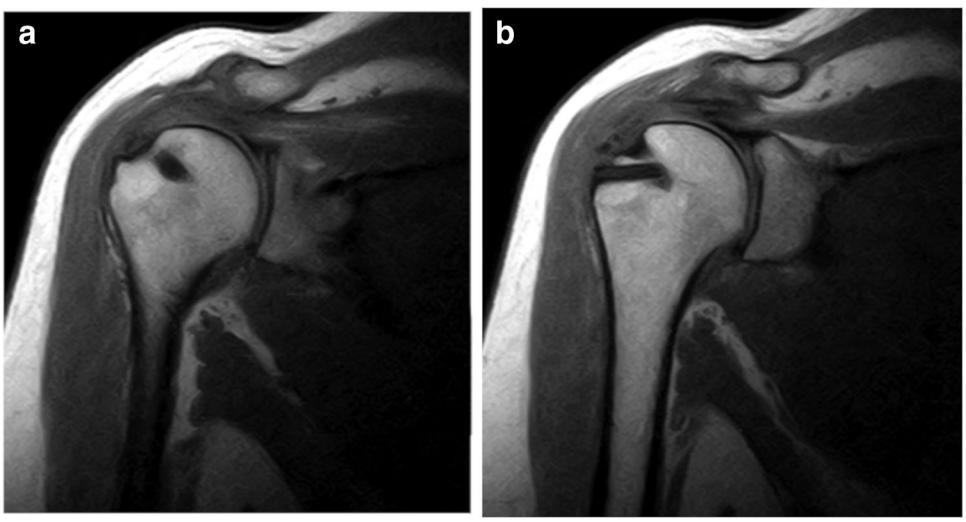

Fig. 6 A postoperative oblique coronal T-2 magnetic resonance imaging of a right shoulder at 12 months showing tendon integrity with no retear. **a** With the single-row technique performed. **b** With the double-row technique performed

bone bed; the tear was closed using a side-to-side suture of the supraspinatus tendon to the subscapular tendon; the debrided tendon was attached to the bloodied humeral bone bed. Lo Ik et al. [12] described a transtendon method that anatomically restored the cuff footprint while maintaining residual lateral insertion. A medial anchor fixes the medial side of the footprint and increases the healing area. Kim Y. S. published the results of a double-row suture with a transtendinous repair and a lateral row anchor for articular and bursal-sided tears [22]. Our study compared prospectively the arthroscopic single-row versus double-row suture bridge fixation in patients with partial-thickness articular-sided rotator cuff tears.

The clinical results published of arthroscopic transtendon repair for partial articular-sided rotator cuff tears showed favourable outcomes. Lo Ik et al. [12] published clinical results from 25 patients with a minimum follow-up of 1 year. All the patients were satisfied with the results and the UCLA score increased from 15 points preoperatively to 32 points postoperatively. Shin S. J. [14]. published the clinical results for 24 patients with an average follow-up of 31 months. The functional results improved significantly. The mean ASES scores increased from 50.8 ± 4.3 preoperatively to 89.1 ± 2.1 postoperatively and the mean Constant shoulder scores increased from 54.8 ± 2.6 to 84.8 ± 2.7 at the end of the follow-up; 92% were satisfied with the surgery. Castagna et al. [18] published the clinical results of 54 patients with an average follow-up of 32 months. The mean UCLA score increased from 14.1 to 32.9 and the Constant shoulder scores from 45.3 to 90.6. Ranalleta et al. [23] published the clinical results of 80 patients with a minimum follow-up of 2 years. The mean ASES scores increased from 44.4 to 76.1. A total of 92.5% of the patients were satisfied with the results. Castricini et al. [15] evaluate 59 cases with an average follow-up of 74 months. The Constant score improved from 47.7 to 84.2.

In our work, 50 patients with an average follow-up duration was 32.5 months, the mean ASES score increased from 35.9 to 96.7 in Group I and from 35.3 to 93.4 in Group II. The mean Constant shoulder scores increased from 55.6 to 97.8 in Group I and from 57.5 to 97.3 in Group II. There were no significant differences in the clinical results between the two groups at the end of the follow-up. In both groups, 5 of the patients (10%) were satisfied with the surgery and 45 were very satisfied (90%).

The overall retear rate of published clinical studies showed variation in the results. Shin S. J [14]. published the results of 24 arthroscopic rotator cuff repairs using the transtendon technique. From the MRI at 6 months, no retears were found and all repairs were completely healed. Castricini et al. [15] in 59 cases evaluated by ultrasound examinations at 74 months and observed retear in 13.9%. In our study at 1 year, retears were found in 2 of the 25 patients in Group I (8%) and 1 in Group II (4%).

With regard to complications, some clinical studies have indicated that the arthroscopic transtendon repair technique is a risk factor for postoperative shoulder stiffness [12, 24]. In our work, one patient in Group I and two patients in Group II had adhesive capsulitis, a result that is consistent with previous studies using this technique [16, 25].

The limitations of this study were the small patient sample and the short follow-up. Therefore, a larger study and longer follow-up would be necessary to evaluate rotator cuff integrity using these arthroscopic techniques. Another limitation is the lack of a control group, such as conservatively treated patients. However, one of the strengths of this work was assessing the clinical outcome of two surgical techniques used to treat partial-thickness articular rotator cuff tears in randomized patients and whose clinical results were compared prospectively, with all patients subjected to MRI to evaluate rotator cuff integrity.

Conclusions

Arthroscopic repair of partial-thickness articular rotator cuff tears that exceed 50% of tendon thickness using a single-row transtendon repair or a double-row suture bridge provides functional improvement and pain relief regardless of the repair technique used. There were no differences in clinical results between both techniques. Consequently, we cannot confirm our working hypothesis. The double-row repairs are more complex procedures and require additional anchor and suture placement with a corresponding increase in operative time and cost.

Funding The authors declare that they have not received any type of financing to realise this work.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval This study was approved by the Ethical Committee of the Hospital Cruz Roja of Córdoba, Spain. Study number assigned is 235/2014.

Right to privacy and informed consent The authors declare that no patient data appeared in this article.

Ethical responsibility Safeguarding of people and animals. The authors declare that for this research no experiments were carried out on human beings or on animals.

Confidentiality and data protection The authors declare that they have followed their work centre's protocols regarding the publication of patient's data.

References

1. Brockmeyer M, Schmitt C, Haupert A, Kohn D, Lorbach O (2017) Limited diagnostic accuracy of magnetic resonance imaging and clinical tests for detecting partial-thickness tears of the rotator cuff. Arch Orthop Trauma Surg 137:1719–1724. https://doi.org/10.1007/s00402-017-2799-3
2. Ellman H (1990) Diagnosis and treatment of incomplete rotator cuff tears. Clin Orthop Relat Res 254:64–74
3. Fukuda H (2003) The management of partial-thickness tears of the rotator cuff. J Bone Joint Surg Br 85:3–11. https://doi.org/10.1302/0301-620X.85B1.13846
4. Lehman RC, Perry CR (2003) Arthroscopic surgery for partial rotator cuff tears. Arthroscopy 19:E81–E84. https://doi.org/10.1016/S0749-8063(03)00692-3
5. Finnan RP, Crosby LA (2010) Partial-thickness rotator cuff tears. J Shoulder Elbow Surg 19:609–616. https://doi.org/10.1016/j.jse.2009.10.017
6. Strauss EJ, Salata MJ, Kercher J, Barker JU, McGill K, Bach BR, Romeo AA, Verma NN (2011) The arthroscopic management of partial-thickness rotator cuff tears. A systematic review of the literature. Arthroscopy 27:568–580. https://doi.org/10.1016/j.arthro.2010.09.019
7. Yamamaka K, Matsumoto T (1994) The joint side tear of the rotator cuff. A follow up study by arthrography. Clin Orthop Relat Res 304:68–73
8. Plachel F, Korn G, Traweger A, Ortmaier R, Resch H, Moroder P (2019) Long-term results after arthroscopic treatment of symptomatic Ellman grade 2 PASTA lesions. J Shoulder Elbow Surg 28:1256–1362. https://doi.org/10.1016/j.jse.2018.12.002
9. Wolff AB, Sethi P, Sutton KM, Covey AS, Magit DP, Medvecky M (2006) Partial-thickness rotator cuff tears. J Am Acad Orthop Surg 14:715–725. https://doi.org/10.5435/00124635-200612000-00003
10. Itoi E, Tabata S (1992) Incomplete rotator cuff tears. Results of operative treatment. Clin Orthop Relat Res 284:128–135
11. Deutsch A (2007) Arthroscopic repair of partial-thickness tears of the rotator cuff. J Shoulder Elbow Surg 16:193–201. https://doi.org/10.1016/j.jse.2006.07.001
12. Lo IK, Burkhart SS (2004) Transtendon arthroscopic repair of partial-thickness, articular surface tears of the rotator cuff. Arthroscopy 20:214–220. https://doi.org/10.1016/j.arthro.2003.11.042
13. Brockmeier SF, Dodson CC, Gamradt SC, Coleman SH, Altchek DW (2008) Arthroscopic intratendinous repair of the delaminated partial-thickness rotator cuff year in overhead athletes. Arthroscopy 24:961–965. https://doi.org/10.1016/j.arthro.2007.08.016
14. Shin S-J (2012) A comparison of 2 repair techniques for partial-thickness articular-sided rotator cuff tears. Arthroscopy 28:25–33. https://doi.org/10.1016/j.arthro.2011.07.005
15. Castricini R, La Camera F, De Gori M, Orlando N, De Benedetto M, Galasso O, Gasparini G (2019) Functional outcomes and repair integrity alter arthroscopic repair of partial articular supraspinatus tendon avulsion. Arch Orthop Trauma Surg 139:369–375. https://doi.org/10.1007/s00402-018-3044-4
16. Ide J, Maeda S, Takagi K (2005) Arthroscopic transtendon repair of partial-thickness articular-side tears of the rotator cuff. Anatomical and clinical study. Am J Sports Med 33:1672–1679. https://doi.org/10.1177/0363546505277141
17. Waibl B, Buess E (2005) Partial-thickness articular surface supraspinatus tears: a new transtendon suture technique. Arthroscopy 21:376–381. https://doi.org/10.1016/j.arthro.2004.11.008
18. Castagna A, Delle Rose G, Conti M, Snyder SJ, Borroni M, Garofalo R (2009) Predictive factors of subtle residual shoulder symptoms after transtendinous arthroscopic cuff-repair: a clinical study. Am J Sport Med 37:103–108. https://doi.org/10.1016/j.arthro.2007.08.016
19. Gonzalez-Lomas G, Kippe MA, Brown GD, Gardner TR, Ding A, Levine WN et al (2008) In situ transtendon repair outperforms tear completion and repair for partial articular-sided supraspinatus tendon tears. J Shoulder Elbow Surg 17:722–728. https://doi.org/10.1016/j.jse.2008.01.148
20. Mazzocca AD, Rincon LM, O´Connor RW et al (2008) Intra-articular partial-thickness rotator cuff tears: analysis of injured and repaired strain behaviour. Am J Sports Med 36:110–116. https://doi.org/10.1177/0363546507307502
21. Lyons TR, Savoie FH 3rd, Field LD (2001) Arthroscopic repair of partial-thickness tears of the rotator cuff. Arthroscopy 17:219–223
22. Kim YS, Lee HJ, Bae SH, Jin H, Song HS (2015) Outcome comparison between in situ repair versus tear completion repair for partial thickness rotator cuff tears. Arthroscopy 31:2191–2198. https://doi.org/10.1016/j.arthro.2015.05.016
23. Ranalletta M, Rossi LA, Bertoa AB et al (2016) Arthroscopic transtendon repair of partial-thickness articular-side rotator cuff tears. Arthroscopy 32:1523–1528. https://doi.org/10.1016/j.arthro.2016.01.027
24. Huberty DP, Schoolfield JD, Brady PC, Vadala AP, Arrigoni P, Burkhart SS (2009) Incidence and treatment of postoperative stiffness following arthroscopic rotator cuff repair. Arthroscopy 25:880–890. https://doi.org/10.1016/j.arthro.2009.01.018
25. Spencer EE Jr (2010) Partial-thickness articular surface rotator cuff tears: an all-inside repair technique. Clin Orthop Relat Res 468:1514–1520. https://doi.org/10.1007/s11999-009-1215-x