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ORIGINAL ARTICLE • SHOULDER - ARTHROSCOPY

Subacromial injection of autologous platelet-rich plasma versus corticosteroid for the treatment of symptomatic partial rotator cuff tears

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Abstract
Objective Rotator cuff tears are one of the most common causes of chronic shoulder pain and disability. They significantly affect the quality of life. Reduced pain and improved function are the goals of conventional therapy, which includes relative rest, pain therapy, physical therapy, corticosteroid injections and surgical intervention. Tendons have a relative avascular nature; hence, their regenerative potential is limited. There is some clinical evidence that the application of autologous platelets may help to revascularize the area of injury in rotator cuff pathologies.
Patients and methods This prospective randomized controlled study was done to evaluate the results of subacromial injection of platelet-rich plasma (PRP) versus corticosteroid injection therapy in 40 patients with symptomatic partial rotator cuff tears. All patients were assessed before injection, 6 weeks, 3 and 6 months after injection, using the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES), the Constant–Murley Score (CMS), the Simple Shoulder Test (SST) and a Visual Analog Scale (VAS) for pain. An MRI was performed before and 6 months after the injection for all the included patients and was graded on 0–5 scale.
Results Both injection groups showed statistically significantly better clinical outcomes over time compared with those before injection. There was a statistically significant difference between RPP group and corticosteroid group 12 weeks after injection, regarding VAS, ASES, CMS and SST in favor of the RPP group. MRI showed an overall slight nonsignificant improvement in grades of tendinopathy/tear in both groups, however, without statistically significant differences between the two groups.
Conclusion PRP injections showed earlier better results as compared to corticosteroid injections, although statistically significant better results after 6 months could not be found. Therefore, subacromial RPP injection could be considered as a good alternative to corticosteroid injection, especially in patients with a contraindication to corticosteroid administration.
Level of evidence II.

Keywords Rotator cuff · Platelet-rich plasma · Corticosteroid · Subacromial impingement syndrome · Shoulder pain

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Introduction

The shoulder is one of the most complex joints in the human body due to its enormous range of motion. Rotator cuff tears (RCT) are one of the most common causes of chronic shoulder pain and disability [1]. This injury is common among athletes. In fact, it can occur to virtually anyone during everyday activities or with chronic overuse. The diagnosis of rotator cuff tendinopathy, with supraspinatus partial thickness tendon tears and tendonosis,

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constitutes more than 50 % of cases presenting with shoulder pains [2].

Many patients are refractory to standard conventional non-operative care, and rehabilitation time can be lengthy. The effectiveness of conservative compared with surgical intervention is unclear. No therapy has been shown to uniformly improve clinical, functional and radiological outcomes for severe grades of RCT, and no therapy specifically targets the presumed degenerative pathology of RCT [3].

It is known that tendons have limited regeneration ability [3]. Hence, new treatment modalities targeting the biology such as platelet-rich plasma (PRP) could be an option for the treatment of this pathology. Chemical modifiers of cellular activity carried in the blood and specifically in its platelets are known to be mitomorphogenic. Its injection might provide the necessary cellular and humeral mediators to induce a healing cascade [4]. There is some clinical evidence that application of autologous platelets may help to revascularize the area of injury, and promote tendon healing. This might improve pain and functional outcomes in rotator cuff pathologies [5–7].

In this prospective randomized controlled study, a question was proposed whether subacromial PRP injection would be utilized to treat patients with painful partial rotator cuff tears instead of the commonly used gold standard corticosteroid injection to improve the clinical, functional and radiological outcomes.

Patients

Forty patients (21 male and 19 female, mean age 51 ± 11 years) between March 2013 and April 2015 were included in this study. Included patients complained of persistent pain in one shoulder for at least 3 months with an MRI evidence of a partial supraspinatus tear. A written consent was approved and signed by all the included patients in this study. A minimum follow-up period of 6 months was an inclusion criterion in this study. Exclusion criteria included: generalized inflammatory arthritis, infection, osteoarthritis of the shoulder, nerve-related symptoms, known malignancy and bleeding disorders.

Patients were allocated sequentially into two parallel groups, the PRP group and the corticosteroid group. Equal randomization (1:1 allocation ratio) was undertaken according to a computer-generated randomization table.

Methods

In the corticosteroid group, patients received a corticosteroid injection [BMS, Kenacort-A 40 mg, (triamcinolone acetonide, suspension)] by means of a 5-ml syringe.

In the PRP group, patients received PRP injection using MyCells Autologous Platelet Preparation System (ProTech, Kaylight, USA). Ten ml of blood was aspirated in MyCells Vacutainer with citrate dextrose anticoagulant. The tube was shaken gently five times to mix the anticoagulant thoroughly with the blood, and it was centrifuged at 3500 RPM for 10 min. This yielded around 6–7 ml of plasma present above the gel separator. The tube was placed in the rack and the cap was removed. The upper 4 ml, which represents the platelet-poor plasma (PPP) phase, was discarded because it contains very low amounts of platelets, growth factors and proteins. The remaining 2–2.5 ml of plasma above the gel was the platelet-rich plasma (PRP) phase.

To harvest the PRP and make full use of the platelets, which form a sticky sedimented layer to the gel surface, the PRP was withdrawn and injected a number of times against the gel. The filter provided was then taken and carefully peeled off the wrapping so as not to contaminate the tube. Holding the filter with the wrapping, the filter was gently pushed in with the brown rubber cap end going inside the PRP tube. The gel separator in the PRP tube was gently touched. The long blunt needle supplied with the kit was then connected to a syringe to withdraw the PRP in the filter, and this constituted the final PRP ready for injection.

In the sitting position, the area to be injected was disinfected under strict aseptic precautions. Posterolateral approach was employed for all the patients in both groups. The point of injection was a soft spot situated 1–2 cm distal and 1 cm medial to the posterolateral corner of the acromion (acromial angle) with the needle directed anteriorly, medially and slightly superiorly for a depth of 3–4 cm. After injection, all patients were allowed to move their shoulders and were instructed to follow a home exercises program. Physiotherapy was not prescribed. Patients were advised to avoid sport activities for 6 weeks. NSAIDs were not allowed for 6 months.

Patients were examined after 6, 12 weeks and 6 months in the outpatient clinic. Outcome measures were the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) [8], the Constant–Murley Score (CMS) [9] and the Simple Shoulder Test (SST) [10]. Patients were also asked to rate their pain on a Visual Analog Scale (VAS) (zero indicating no pain and ten the worst possible pain).

MRI was performed 6 months after injection. MRIs were graded on a 0–5 scale (modified from Lewis [11] by Scarpone et al. [12]). Grades were: 0, no tendinopathy (normal tendon signal); 1, mild tendinopathy (tendon edema); 2, moderate tendinopathy (tendon edema, hypoechoic areas, neovascularization and/or bursal involvement); 3, moderate tendinopathy + partial thickness tear present; 4, severe tendinopathy (moderate tendinopathy + fatty

infiltration) ± partial thickness tear present; and 5, severe tendinopathy + full thickness tear present.

Statistical analysis

Independent-sample two-tailed *t* tests were used to analyze mean differences of ASES, CMS and SST between PRP and corticosteroid groups. The significance level was set at 0.05 at which the null hypothesis (mean differences equal zero) was rejected so that *p* values ≥0.05 are statistically nonsignificant, *p* values <0.05 are significant and *p* values <0.01 are highly significant. Fisher's exact test was performed for analysis of the MRI changes. Statistical analysis was done using SPSS software.

Results

Twenty patients (mean age 52 ± 12 years) participated in the PRP group and 20 patients (mean age 50 ± 10 years) in the corticosteroid group (nonsignificant, n.s.). There were 10 males and 10 females in the PRP group, while 11 males and 9 females represented the corticosteroid group (n.s.). Eleven injections into the right shoulder and 9 into the left shoulder were administered in the PRP group. On the other hand, 12 injections into the right shoulder and 8 into the left shoulder were administered in the corticosteroid group (n.s.). Infection did not take place in any of the studied cases.

In comparison with the baseline before injection, all patients in both groups had statistically significant better ASES, CMS and SST shoulder scores and pain relief in VAS after injection (Table 1).

Comparing both groups at 6-week, 12-week and 6-month time points, patients in the PRP group were significantly better only at 12 weeks in SST ($p = 0.013$; Table 2; Fig. 1), ASES ($p \leq 0.001$; Table 3; Fig. 2), CMS ($p = 0.001$; Table 4) (Fig. 3) and VAS ($p = 0.01$) as compared to the corticosteroid group.

MRI showed a slight nonsignificant improvement in grades of tendinopathy/tear in both groups. No statistically significant difference was found between the two groups ($p = 0.450$) (Table 5).

Table 2 SST of the PRP and corticosteroid groups over time (pre-injection, 6, 12 weeks and 6 months)

	PRP group	Corticosteroid group	*p* value
Pre-injection	6.3 ± 3	5.6 ± 3.1	0.472
6 weeks	8.2 ± 2.5	8.5 ± 2.8	0.723
12 weeks	10.2 ± 1.8	8.2 ± 2.9	0.013
6 months	10.2 ± 1.8	9.2 ± 2.7	0.176

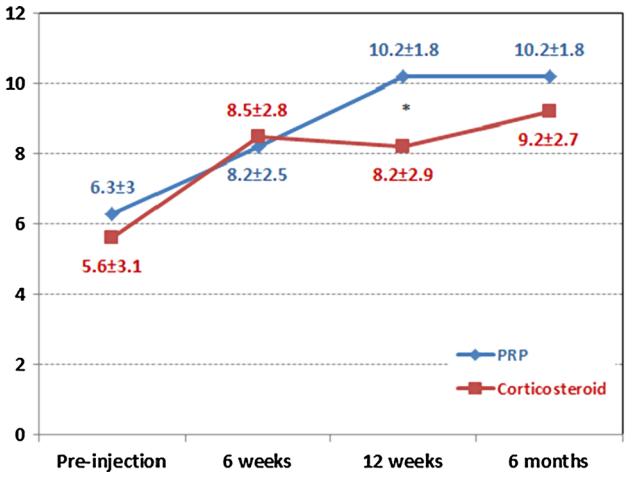

Fig. 1 SST of the PRP and corticosteroid groups over time (pre-injection, 6, 12 weeks and 6 months). *Asterisk* significant difference between the PRP and corticosteroid groups

Table 3 ASES of the PRP and corticosteroid groups over time (pre-injection, 6, 12 weeks and 6 months)

	PRP group	Corticosteroid group	*p* value
Pre-injection	52.6 ± 16	52.5 ± 15	0.983
6 weeks	73.7 ± 15.6	72.9 ± 16.4	0.875
12 weeks	86.6 ± 12.2	68.7 ± 12.3	<0.001
6 months	83.4 ± 16.1	78.9 ± 13.2	0.340

Discussion

Corticosteroid injection is widely used for treatment of patients with different shoulder pathologies and pain [13]. Short-term pain relief was noticed after injection [14].

Table 1 *p* values of paired *t* tests of the PRP and corticosteroid groups for ASES, CMS and SST

Group	Score	Baseline—6 weeks	Baseline—12 weeks	Baseline—6 months
PRP	ASES	<0.01	<0.01	<0.01
	CMS	<0.01	<0.01	<0.01
	SST	<0.01	<0.01	<0.01
Corticosteroid	ASES	<0.01	<0.01	<0.01
	CMS	<0.01	<0.01	<0.01
	SST	<0.01	<0.01	<0.01

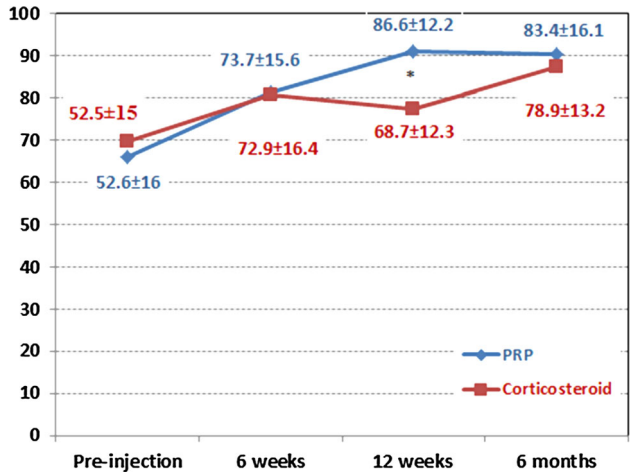

Fig. 2 ASES of the PRP and corticosteroid groups over time (pre-injection, 6, 12 weeks and 6 months). *Asterisk* significant difference between the PRP and corticosteroid groups

Table 4 CMS of the PRP and corticosteroid groups over time (pre-injection, 6, 12 weeks and 6 months)

	PRP group	Corticosteroid group	*p* value
Pre-injection	66 ± 21	69.7 ± 19.4	0.566
6 weeks	81.4 ± 16	80.6 ± 13	0.863
12 weeks	90.9 ± 8.1	77.4 ± 15.3	0.001
6 months	90.5 ± 8.3	87.3 ± 12.2	0.338

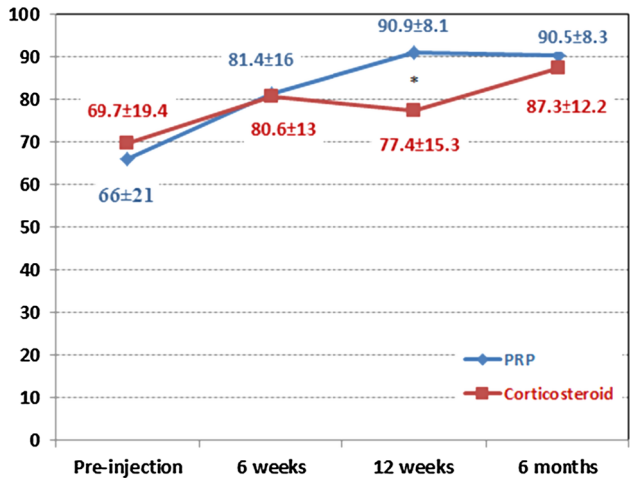

Fig. 3 CMS of the PRP and corticosteroid groups over time (pre-injection, 6, 12 weeks and 6 months). *Asterisk* significant difference between the PRP and corticosteroid groups

However, its use carries many potential risks that should also be taken into consideration [14]. Over more, subsequent tendon weakness and rupture are potential complications [15].

Many studies done on animal models have proven the beneficial effects of growth factors on tendon healing [16, 17]. This was shown for platelet concentrates and other new different treatment modalities targeting the biology. This in turn includes: bone morphogenetic proteins (BMP), transforming growth factors (TGFs) and fibroblast growth factors (FGFs) [18, 19]. The use of these agents proved promoting tendon cell proliferation, collagen synthesis and vascularization in vitro and in vivo [20, 21]. Many studies in the literature recommended the use of PRP for the treatment of rotator cuff tendinopathies [11, 22, 23]. Scarpone et al. [12] found statistically significant long-standing improvement in pain, function and MRI outcomes in 19 shoulders within 18 patients with refractory rotator cuff tendinopathy. Rha et al. [24] found better results for PRP injections as compared to dry needling in patients with partial rotator cuff tears or tendinopathy. Many other studies have shown favorable results of rotator cuff tear surgery with the use of PRP, platelet leukocyte membrane, platelet-rich fibrin matrix or plasma rich in growth factors [7, 25–28].

In contrast to the above-mentioned studies supporting the PRP use, Kesikburun et al. [29] compared injecting PRP and saline for the treatment of rotator cuff tendinopathy or partial tendon ruptures and found no difference after a 1-year follow-up. Other studies that evaluated the use of PRP during shoulder surgery found no additional benefit [25, 30–39].

The most striking feature of the results of the current study was the better outcome after 12 weeks in the PRP group in comparison with the corticosteroid group. Improved shoulder scores (ASES, CMS and SST) and VAS were statistically significant after 12 weeks. However, after 6 months no differences, in terms of shoulder function, were found between both groups. Both groups showed a statistically significantly better shoulder function after subacromial injection over time compared with the baseline time point.

Regarding the MRI changes after PRP injection, the literature is quite controversial, and while some studies described improvement [7, 12, 25, 26, 30, 40], others described no improvement [31, 32, 35, 38], or even deterioration [39].

In the current study, MRI changes in both treatment groups did not show any definite significant trend. This could indicate that MRI may lack both the sensitivity and specificity as a follow-up tool for the types of changes occurring.

A shortcoming of the study is that the injections were not ultrasound guided and the accurate place of injection except being subacromial could not be checked. Other shortcomings include: the small number of patients and the

Table 5 Tendinopathy/partial tears MRI grades before and after injection of PRP and corticosteroid

Grade	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Pre-PRP injection				80	20	
6 m Post-PRP injection	5	5	15	45	25	5
Pre-steroid injection				75	25	
6 m Post-steroid injection			10	60	25	5

short-term follow-up. Further studies with a larger number of patients and longer follow-up periods are needed.

This study was a trial to add new data to the discussion about the value of PRP as an alternative to corticosteroids injection for the treatment of a symptomatic supraspinatus partial tear. In addition, efforts should be made to decrease the cost of PRP, thus improving cost-effectiveness.

No specific definitive MRI findings were found in this study in any of the studied cases in both groups.

Conclusion

In conclusion, subacromial autologous platelet-rich plasma (PRP) injection for treatment of a partial supraspinatus tendon tear is comparable to the standard corticosteroid injection. Moreover, more favourable clinical results are noticed at 3 months, although no statistically significant improvement in the outcome measures could be demonstrated at 6 months after injection. Therefore, the subacromial RPP injection could be a quite good alternative to corticosteroid injection, especially in patients with a contraindication to corticosteroid injection.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interests for this study. No funds have been received for this study by any of the authors. It was performed at University Public Hospital. The presenting author, Mohamed El-Sayed, declares that he has no conflict of interest. The first author, Ahmed Shams, declares that he has no conflict of interest. The third author, Osama Gamal, declares that he has no conflict of interest. The fourth author, Waled Ewes, declares that he has no conflict of interest.

Ethical approval This study was performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. It was conducted after approval of the university ethical committee, and a written approval statement was collected from all the included subjects before surgery. This study was conducted at Menofiya University Hospitals and Tanta University Hospitals.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Chakravarty K, Webley M (1993) Shoulder joint movement and its relationship to disability in the elderly. J Rheumatol 20(8):1359–1361
2. Kim HM, Dahiya N, Teefey SA et al (2010) Location and initiation of degenerative rotator cuff tears. J Bone Joint Surg (Am) 92(5):1088–1096
3. Ho JO, Sawadkar P, Mudera V (2014) A review on the use of cell therapy in the treatment of tendon disease and injuries. J Tissue Eng 18(5):204–213
4. Anitua E, Andía I, Sanchez M et al (2005) Autologous preparations rich in growth factors promote proliferation and induce VEGF and HGF production by human tendon cells in culture. J Orthop Res 23:281–286
5. De Vos RJ, Weir A, Van Schie HT et al (2010) Platelet-rich plasma injection for chronic Achilles tendinopathy: a randomized controlled trial. JAMA 303(2):144–149
6. Peerbooms JC, Sluimer J, Bruijn DJ, Gosens T (2010) Positive effect of an autologous platelet concentrate in lateral epicondylitis in a double-blind randomized controlled trial: platelet-rich plasma versus corticosteroid injection with a 1-year follow-up. Am J Sports Med 38(2):255–262
7. Randelli P, Arrigoni P, Ragone V, Aliprandi A, Cabitza P (2011) Platelet rich plasma in arthroscopic rotator cuff repair: a prospective RCT study, 2-year follow-up. J Shoulder Elbow Surg 20:518–528
8. Richards RR, An KN, Bigliani LU et al (1994) A standardized method for the assessment of shoulder function. J Shoulder Elbow Surg 3(6):347–352
9. Constant CR, Murley AG (1987) A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 214:160–164
10. Lippitt SB, Harryman DT, Matsen FA, Fu FH, Hawkins RJ (1993) A practical tool for evaluating function: the simple shoulder test. In: Matsen F (ed) The shoulder: a balance of mobility and stability, American Academy of Orthopaedic Surgeons, pp 501–18
11. Lewis JS (2010) Rotator cuff tendinopathy: a model for the continuum of pathology and related management. Br J Sports Med 44(13):918–923
12. Scarpone M, Rabago D, Snell E et al (2013) Effectiveness of platelet-rich plasma injection for rotator cuff tendinopathy: a prospective open-label study. Glob Adv Health Med 2(2):26–31
13. Molini L, Mariacher S, Bianchi S (2012) US guided corticosteroid injection into the subacromial-subdeltoid bursa: technique and approach. J Ultrasound 15(1):61–68
14. Zheng XQ, Li K, Wei YD, Tie HT, Yi XY, Huang W (2014) Nonsteroidal anti-inflammatory drugs versus corticosteroid for treatment of shoulder pain: a systematic review and meta-analysis. Arch Phys Med Rehabil 95(10):1824–1831
15. Haraldsson BT, Langberg H, Aagaard P, Zuurmond AM, Van El B, Degroot J et al (2006) Corticosteroids reduce the tensile strength of isolated collagen fascicles. Am J Sports Med 34(12):1992–1997

16. Hansen M, Boesen A, Holm L, Flyvbjerg A, Langberg H, Kjaer M (2013) Local administration of insulin-like growth factor-I (IGF-I) stimulates tendon collagen synthesis in humans. Scand J Med Sci Sports 23(5):614–619
17. Kaux JF, Janssen L, Drion P et al (2014) Vascular Endothelial Growth Factor-111 (VEGF-111) and tendon healing: preliminary results in a rat model of tendon injury. Muscles Ligaments Tendons J 4(1):24–28
18. Rutgers M, Saris DB, Dhert WJ, Creemers LB (2010) Cytokine profile of autologous conditioned serum for treatment of osteoarthritis, in vitro effects on cartilage metabolism and intra-articular levels after injection. Arthritis Res Ther 12(3):213–222
19. Cervellin M, De Girolamo L, Bait C, Denti M, Volpi P (2012) Autologous platelet-rich plasma gel to reduce donor-site morbidity after patellar tendon graft harvesting for anterior cruciate ligament reconstruction: a randomized, controlled clinical study. Knee Surg Sports Traumatol Arthrosc 20(1):114–120
20. Bosch G, Moleman M, Barneveld A, van Weeren PR, van Schie HT (2011) The effect of platelet-rich plasma on the neovascularization of surgically created equine superficial digital flexor tendon lesions. Scand J Med Sci Sports 21(4):554–561
21. Heisterbach PE, Todorov A, Fluckiger R, Evans CH, Majewski M (2012) Effect of BMP-12, TGF-beta1 and autologous conditioned serum on growth factor expression in Achilles tendon healing. Knee Surg Sports Traumatol Arthrosc 20(10):1907–1914
22. Nguyen RT, Borg-Stein J, McInnis K (2011) Applications of platelet-rich plasma in musculoskeletal and sports medicine: an evidence-based approach. PM R 3(3):226–250
23. Cook JL, Purdam CR (2009) Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load induced tendinopathy. Br J Sports Med 43(6):409–416
24. Rha DW, Park GY, Kim YK, Kim MT, Lee SC (2013) Comparison of the therapeutic effects of ultrasound-guided platelet-rich plasma injection and dry needling in rotator cuff disease: a randomized controlled trial. Clin Rehabil 27(2):113–122
25. Barber FA, Hrnack SA, Snyder SJ, Hapa O (2011) Rotator cuff repair healing influenced by platelet-rich plasma construct augmentation. Arthroscopy 27(8):1029–1035
26. Gumina S, Campagna V, Ferrazza G et al (2012) Use of platelet leukocyte membrane in arthroscopic repair of large rotator cuff tears: a prospective randomized study. J Bone Joint Surg Am 94(15):1345–1352
27. Randelli PS, Arrigoni P, Cabitza P, Volpi P, Maffulli N (2008) Autologous platelet rich plasma for arthroscopic rotator cuff repair. A pilot study. Disabil Rehabil 30(20–22):1584–1589
28. Jo CH, Shin JS, Lee YG et al (2013) Platelet-rich plasma for arthroscopic repair of large to massive rotator cuff tears: a randomized, single-blind, parallel-group trial. Am J Sports Med 41:2240–2248
29. Kesikburun S, Tan AK, Yilmaz B, Yasar E, Yazicioglu K (2013) Platelet-rich plasma injections in the treatment of chronic rotator cuff tendinopathy: a randomized controlled trial with 1-year follow-up. Am J Sports Med 41(11):2609–2616
30. Antuna S, Barco R, Martinez Diez JM, Sanchez Marquez JM (2013) Platelet-rich fibrin in arthroscopic repair of massive rotator cuff tears: a prospective randomized pilot clinical trial. Acta Orthop Belg 79(1):25–30
31. Castricini R, Longo UG, De BM et al (2011) Platelet-rich plasma augmentation for arthroscopic rotator cuff repair: a randomized controlled trial. Am J Sports Med 39(2):258–265
32. Weber SC, Kauffman JI, Parise C, Weber SJ, Katz SD (2013) Platelet-rich fibrin matrix in the management of arthroscopic repair of the rotator cuff: a prospective, randomized, double blinded study. Am J Sports Med 41(2):263–270
33. Chahal J, Van Thiel GS, Mall N et al (2012) The role of platelet rich plasma in arthroscopic rotator cuff repair: a systematic review with quantitative synthesis. Arthroscopy 28(11):1718–1727
34. Malavolta EA, Gracitelli ME, Ferreira Neto AA, Assuncao JH, Bordalo-Rodrigues M, De Camargo OP (2014) Platelet-rich plasma in rotator cuff repair: a prospective randomized study. Am J Sports Med 42(10):2446–2454
35. Zhang Q, Ge H, Zhou J, Cheng B (2013) Are platelet-rich products necessary during the arthroscopic repair of full-thickness rotator cuff tears: a meta-analysis. Am J Sports Med 22(4):213–221
36. Rodeo SA, Delos D, Williams RJ, Adler RS, Pearle A, Warren RF (2012) The effect of platelet-rich fibrin matrix on rotator cuff tendon healing: a prospective, randomized clinical study. Am J Sports Med 40(6):1234–1241
37. Jo CH, Kim JE, Yoon KS et al (2011) Does platelet-rich plasma accelerate recovery after rotator cuff repair? A prospective cohort study. Am J Sports Med 39(10):2082–2090
38. Ruiz-Moneo P, Molano-Munoz J, Prieto E, Algorta J (2013) Plasma rich in growth factors in arthroscopic rotator cuff repair: a randomized, double-blind, controlled clinical trial. Arthroscopy 29(1):2–9
39. Bergeson AG, Tashjian RZ, Greis PE, Crim J, Stoddard GJ, Burks RT (2012) Effects of platelet-rich fibrin matrix on repair integrity of at-risk rotator cuff tears. Am J Sports Med 40(2):286–293
40. Charousset C, Zaoui A, Bellaiche L, Piterman M (2014) Does autologous leukocyte-platelet-rich plasma improve tendon healing in arthroscopic repair of large or massive rotator cuff tears? Arthroscopy 30(4):428–435