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ORIGINAL ARTICLE • KNEE - ARTHROPLASTY

Should orthopedic surgeons consider reducing the negative effects of Outerbridge grade 2 patellofemoral chondral lesion on early postoperative recovery during anterior cruciate ligament reconstruction

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Abstract

Purpose The purpose of this study was to comparatively evaluate the effectiveness of intra-articular PRP and HA injections applied as the treatment of Outerbridge grade 2 chondral lesions in patellofemoral joint during arthroscopic ACL reconstruction.

Methods The clinical and radiographic data of 61 patients between 18 and 45 years of age were evaluated. The patients were separated into three groups. Hyaluronic acid injection was applied in 22 knees (Group 1), PRP injection was applied in 18 knees (Group 2), and 21 knees did not have any specific treatment except ACL reconstruction (Group 3). All patients were followed clinically at least for 12 months. Clinical examination of the operated knee, visual analogue scale (VAS) score, Lysholm knee score, and Tegner activity scale were the outcome measures. Routine X-ray and MRI were also performed for all patients at 12-month postoperative follow-up visit.

Results Although the mean VAS and Lysholm scores at 3-month follow-up were better in Group 1 and 2 than Group 3, the efficacy of intra-articular PRP on healing process regarding progression of the mean VAS and Lysholm scores through 6- and 12-month follow-ups was significantly better and longer than HA. No statistically significant differences were detected according to Tegner activity scale between the groups at 3 and 6 months; however, Group 2 had better activity level than both Group 1 ($p < 0.001$) and 3 ($p < 0.001$) at the end of 12 months after surgery.

Conclusion Intra-articular PRP injection applied as the treatment of concomitant Outerbridge grade 2 chondral lesion in patellofemoral joint during ACL reconstruction revealed better and durable clinical outcomes via decreasing the potentially negative effects of chondral pathology on postoperative healing with respect to HA injection.

Level of evidence III—retrospective comparative study.

Keywords Anterior cruciate ligament · Cartilage · Patellofemoral joint

Introduction

Anterior cruciate ligament (ACL) rupture has been reported as the most common injury leading to an unstable knee joint [10]. During the last decades, optimizing the clinical outcomes after arthroscopic ACL reconstruction has been one of the main objectives of orthopedic research [9, 14, 18]. However, accompanying injuries of other intra-articular structures such as the menisci, cartilage, or ligaments during the surgical management may still be a leading cause for poorer clinical outcomes than expected despite the excellent reconstruction techniques and fixation methods [23]. It was demonstrated that especially the presence of a focal

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chondral lesion at the time of ACL reconstruction leads to impaired short-term and mid-term patient-reported outcomes as well as an increased risk of later osteoarthritis (OA) [5, 19, 20]. Cartilage tissue of the patellofemoral joint surfaces may become susceptible to the secondary injury due to disturbed stability resulting in disproportionate transfer of the mechanical forces around the ACL-deficient knee joint during motion [8, 24]. Various concomitant surgical interventions which can be performed during the same surgery with ACL reconstruction have been described for the treatment of Outerbridge grade 3 or 4 focal chondral lesions including arthroscopic debridement, microfracture (MFX), osteochondral grafting, and autologous chondrocyte implantation (ACI) [15, 16]. On the other hand, treatment of Outerbridge grade 1 or 2 chondral lesions in ACL-deficient knee is controversial [6].

As the importance of understanding the biological processes behind the clinical course of recovery after surgical interventions for concomitant chondral lesions in ACL-deficient knee has been considered more prominently, the researchers have put an increasing effort to develop novel strategies including biological enhancement methods to achieve a faster and more effective recovery [1, 12, 17, 26]. Platelet-rich plasma (PRP), which contains several bioactive molecules that might promote tissue healing, has become more widely used in sports medicine mainly because of its advantage of using the patient's own growth factors and ease of preparation [1, 7, 21]. Nevertheless, among the available pharmacologic solutions, intra-articular hyaluronic acid (HA) has also been widely used in clinical practice with good results [25].

The purpose of this study was to comparatively evaluate the effectiveness of intra-articular PRP and HA injections applied as the treatment of Outerbridge grade 2 chondral lesions in patellofemoral joint during arthroscopic ACL reconstruction. We hypothesized that PRP would decrease the potentially negative effects of concomitant patellofemoral lesion on postoperative healing better than HA injection in patients surgically treated for ACL rupture.

Materials and methods

The present study retrospectively evaluated the clinical and radiographic data of the patients who underwent surgical treatment for ACL rupture. The inclusion criteria were primary ACL reconstruction performed for symptomatic rupture leading to pain and instability, isolated lesion without any accompanying meniscal and/or ligamentous injury, age between 18 and 45 years at the time of surgical intervention, Outerbridge grade 2 chondral lesion in patellofemoral joint according to arthroscopic evaluation during the ACL surgery, no radiographic signs of OA, and the absence of any chondral lesion in medial and lateral femoral condyles as well as tibial plateau. Between January 2013 and January 2016, 151 consecutive patients were operated. The patients who were < 18 and > 45 years of age, with chronic inflammatory or rheumatologic disease, a past medical history of intra-articular fracture or meniscectomy, accompanying chondral lesion in the medial or lateral compartment of the knee, and the ones who had incomplete or insufficient clinical records or lost to follow-up, were excluded. The clinical and radiographic data of 61 patients were evaluated after having approval from the institutional review board (Fig. 1).

The study group consisted of 6 women and 55 men. All patients were followed up for at least 12 months. The mean age of the patients was 29.2 ± 7.5 years (range 18–45 years). All patients had unilateral knee joint involvement. Preoperative MRI was obtained for all knees to establish differential diagnoses and prove ACL rupture suspected on physical examination. All patients had mechanical symptoms preoperatively, and thus, none of the patients had intra-articular injection or physical therapy as conservative treatment measures prior to surgery.

The patients were separated into three groups according to the treatment modality, which was the concomitant intervention for Outerbridge grade 2 chondral lesion of patellofemoral joint during primary arthroscopic ACL reconstruction, preferred by three different orthopedic surgeons (HS applied HA; YC applied PRP; AI did not apply any additional treatment). Hyaluronic acid injection (Arthrohyal®, Pronovis GmbH, Munchen, Germany) containing 44 mg fermented source sodium hyaluronate with the molecular weight between 1.5 and 1.8 MDa per syringe (2.2%) was applied in 22 knees (Group 1). Platelet-rich plasma injections were applied in 18 knees (Group 2) after preparation using a single-spin system (Orthopras®, Proteal Bioregenerative Solutions, Barcelona, Spain) that concentrates platelets and separates red blood cells (RBCs) as well as white blood cells (WBCs) from the venous blood drawn as 10 ml and centrifugated at 1500 rpm for 5 min to yield 4 ml of PRP. Twenty-one knees (Group 3) did not have any specific treatment for patellofemoral chondropathy during the ACL reconstruction surgery. All surgical procedures were performed by three of the authors who also determined the Outerbridge classification of chondral lesions together intra-operatively (HS, YC, and AI). All lesions were Outerbridge grade 2 characterized by partial thickness defect with fissures on the surface that do not reach subchondral bone (Fig. 2). During the surgery, arthroscopic examinations were first performed to confirm the preoperative diagnosis as well as concomitant intra-articular pathologies. Following ACL procedure completed using anatomic single-bundle reconstruction technique with four-strand hamstring autograft, intra-articular HA or PRP injections were performed

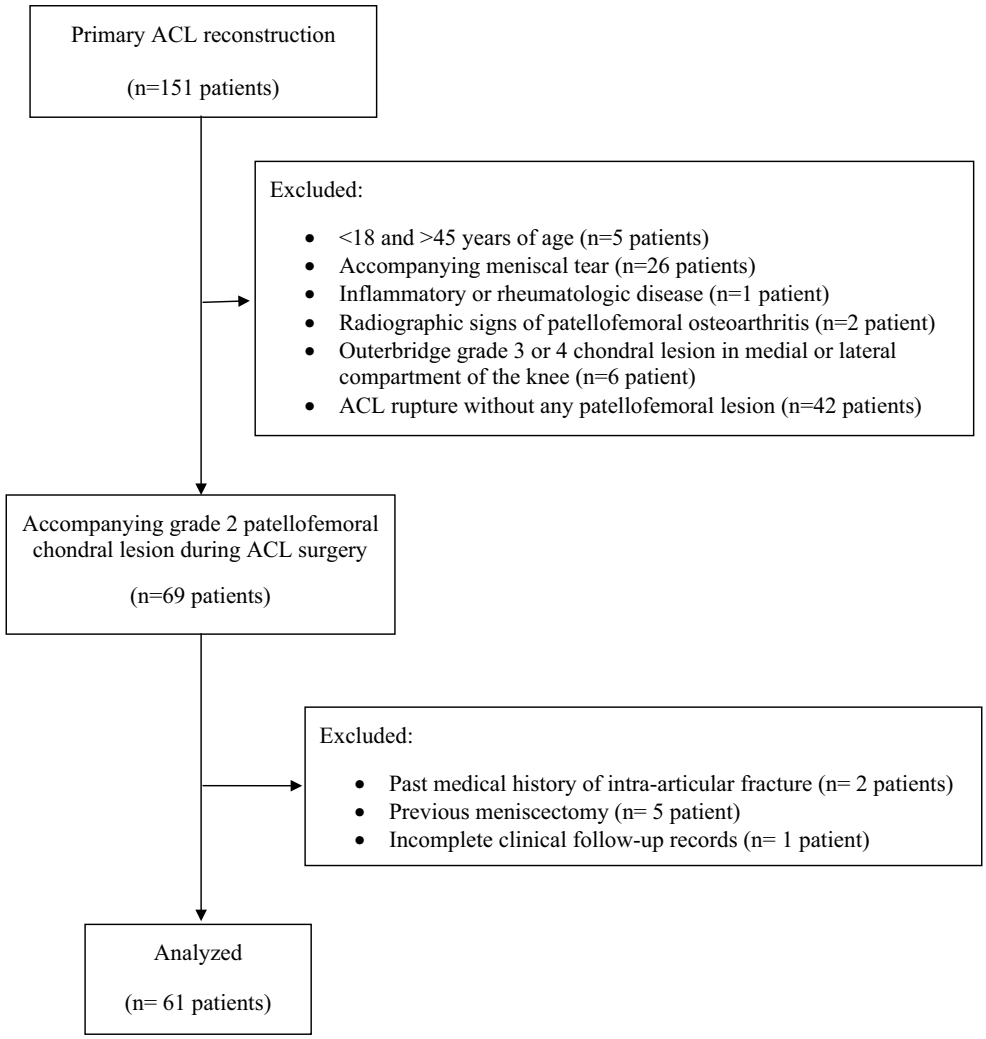

Fig. 1 Flowchart demonstrating the excluded patients

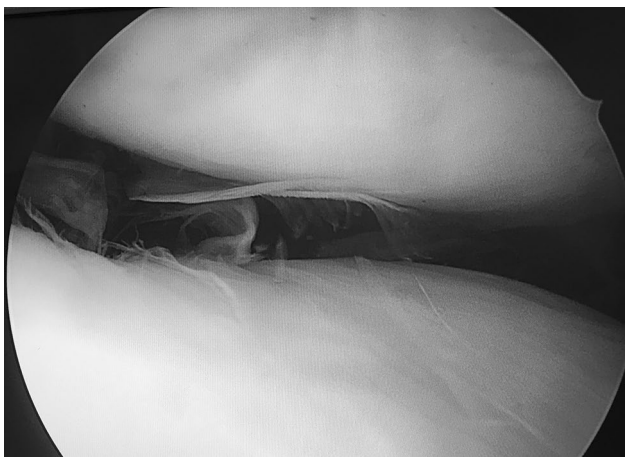

Fig. 2 Arthroscopic image of Outerbridge grade 2 chondral lesion in the patellofemoral joint during ACL reconstruction

in dry conditions as the final step of surgery just after wound closure.

A standard rehabilitation protocol focused on early knee range of motion (ROM) and restoration of quadriceps function was utilized for all patients. No postoperative bracing was used. Active and passive motion exercises as well as the isometric quadriceps exercises were started at the first postoperative day; however, maximum knee flexion did not exceed 90 degrees till the end of the fourth week after surgery. Continuous passive motion (CPM) was applied for a total of 2 h per day. The patients were not allowed weight-bearing during the first month postoperatively. Then, progressive partial weight-bearing was allowed starting from the end of the fourth week, and after 6 weeks, full weight-bearing with full range of motion. Low-impact sports activities such as swimming were permitted at the end of the sixth month postoperatively; however, limited-contact sports activities such as football were not permitted till the

end of the first year. After completion of 6 months following the surgery, decision on the exact timing for return to low-impact sports activities left to the patient and the time passed from surgery to return to sports activities was noted for each patient.

All patients were followed clinically at least for 12 months. The mean follow-up time was 17.1 ± 5.9 months (range 12–36 months). Clinical examination including patellar compression and anterior drawer tests as well as ROM measurement of the operated knee, visual analogue scale (VAS) score, Lysholm knee score, and Tegner activity scale was the instruments used as outcome measures to evaluate the clinical status of the patients preoperatively and at 3, 6, and 12 months postoperatively. The time from surgery up to return to non-impact sports activities was also noted for all patients. Routine X-ray and MRI were also performed for all patients at 12-month postoperative follow-up visit. Any radiographic sign of patellofemoral arthritis such as subchondral sclerosis, cystic degeneration, or osteophyte formation was recorded according to standing anteroposterior and lateral X-ray images. Magnetic resonance imaging evaluation was performed using a 1.5-Tesla MRI unit (Philips, Amsterdam, Netherlands). Intra-articular effusion, edema, or cyst formation in the subchondral bone, any chondral damage to the patellofemoral joint surfaces, and any adhesions were evaluated and noted when observed according to MRI at 12 months postoperatively.

Statistical analysis was achieved using paired *t* test and Wilcoxon signed-rank test to compare related data of preoperative and postoperative periods and, Mann–Whitney U test to compare independent interval data regarding differences of the patient groups according to pain in patellofemoral compression test, postoperative time to return to sports activities, and MRI findings. The level of significance was set at $p \leq 0.05$.

Results

Demographic data of the patients are given in Table 1. Progression of the clinical examination findings and scores from preoperative period through the 12-month follow-up is demonstrated in Table 2. A positive patellofemoral compression

Table 2 Progression of the clinical examination findings and scores from preoperative period through the 12 months postoperatively

	Pre-op	3 months	6 months	12 months
Positive patellofemoral compression test (*n*)				
Group 1	10	5	8	12
Group 2	12	5	5	7
Group 3	13	12	12	15
Positive anterior drawer test (*n*)				
Group 1	22	0	0	1
Group 2	18	0	0	1
Group 3	21	0	1	2
Range of motion (degrees)				
Group 1	133 ± 6.6	124.8 ± 7.5	128.6 ± 4.8	130.7 ± 4.8
Group 2	130 ± 7.1	126.4 ± 7	127.8 ± 4.5	130.8 ± 4.8
Group 3	131 ± 6.5	122.8 ± 7.1	129 ± 5	127.6 ± 5.9
VAS score (points)				
Group 1	5.3 ± 1.1	2.6 ± 0.8	2 ± 1	1.8 ± 0.9
Group 2	5 ± 1.3	2.5 ± 1.1	1.1 ± 0.9	0.8 ± 0.6
Group 3	5.1 ± 1.3	3.8 ± 1	2 ± 0.9	1.7 ± 1
Lysholm score (points)				
Group 1	48 ± 8.9	80.8 ± 7	81.9 ± 7.8	84.7 ± 6.5
Group 2	51.2 ± 9.3	80 ± 11	90.5 ± 6.9	92.9 ± 6.2
Group 3	50.4 ± 12.3	69.7 ± 8.6	80 ± 6.4	82.7 ± 7.2
Tegner scale score (points)				
Group 1	1.6 ± 0.5	1.8 ± 0.8	2.1 ± 0.4	2.4 ± 0.7
Group 2	1.2 ± 0.6	1.7 ± 0.6	2.3 ± 0.5	3.5 ± 0.8
Group 3	1.5 ± 0.5	1.7 ± 0.5	2 ± 0.4	2.5 ± 0.7

Table 1 Demographic data of the patients

	Group 1 (*n* = 22)	Group 2 (*n* = 18)	Group 3 (*n* = 21)
Mean age (years)	30.4 ± 7.1	31.3 ± 8.4	26 ± 6.5
Gender			
Male	20	15	20
Female	2	3	1
Mean BMI (kg/m^2)	23.7 ± 1.9	23.5 ± 2	24 ± 1.8
Side			
Left knee	10	8	14
Right knee	12	10	7
Mechanism of injury			
Contact	13	13	11
Non-contact	9	5	10
Mean time to surgery (months)	6.7 ± 1.9	5.9 ± 1.8	6.2 ± 2.2

test was significantly more common in Group 3 than in Group 2 at 12-month clinical examination ($p=0.041$). Statistically significant difference regarding patellofemoral compression test was also detected between Group 1 and 3 at 3-month follow-up ($p=0.030$); however, 6- and 12-month follow-ups revealed similar results ($p=0.227$ and $p=0.479$). The prevalence of a positive patellofemoral compression test was also similar between Group 1 and 2 at all follow-ups ($p=0.730$, $p=0.564$, and $p=0.359$). Anterior drawer test was positive in all patients preoperatively. During the postoperative period, 1 knee from Group 1, 1 knee from Group 2, and 2 knees from Group 3 became anterior drawer test positive and on the other hand, none of those were diagnosed with re-rupture of the reconstructed ACL according to MRI obtained at 12-month follow-up. The mean VAS scores in both Group 1 and 2 were significantly better than Group 3 at 3-month follow-up ($p<0.001$ and $p=0.001$) (Fig. 3). At the 6-month and 12-month controls, the mean VAS scores in Group 2 were still significantly better than Group 3 ($p=0.008$ and $p<0.001$); however, no significant differences between Group 1 and 3 were detected at these intervals ($p>0.999$ and $p=0.687$). Group 2 had better VAS scores compared to Group 1 at 6-month and 12-month follow-ups ($p=0.004$ and $p<0.001$). The mean Lysholm scores in Group 2 were significantly better than Group 3 at all of the 3-, 6-, and 12-month follow-ups ($p=0.003$, $p<0.001$, and $p<0.001$) (Fig. 4). Although better mean Lysholm scores were noted in Group 2 with respect to Group 3 at all postoperative controls, Group 1 demonstrated better scores than Group 3 only at 3-month follow-up ($p<0.001$). No significant differences were observed at 6 and 12-month postoperatively ($p=0.386$ and $p=0.345$). When Group 1 and 2 were compared, better Lysholm scores in Group 2 at 6-month and 12-month follow-ups were noted ($p<0.001$ and $p<0.001$). No significant differences were detected according to Tegner activity scale between the groups at 3 and 6 months; however, Group 2 had better activity level than both Group 1 ($p<0.001$) and 3 ($p<0.001$)

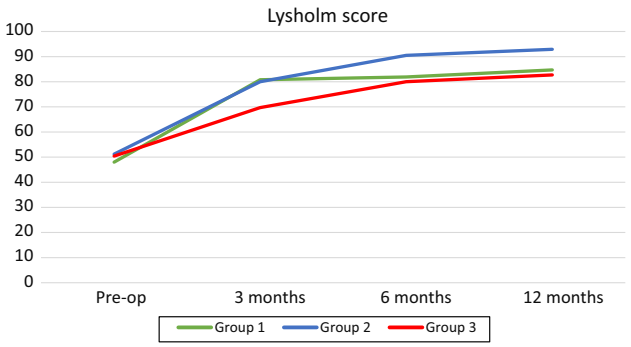

Fig. 4 Graph demonstrating the Lysholm score changes

at the end of 12 months after surgery (Fig. 5). The mean time from surgery to return to non-impact sports activities was 9.2 ± 2.2 months (range 6–12 months) in Group 1, 7 ± 1.9 months (range 6–12 months) in Group 2, and 9 ± 2.8 months (range 6–12 months) in Group 3. The patients in Group 2 returned to sports activities significantly earlier than Group 1 ($p=0.001$) and Group 3 ($p=0.012$).

According to X-ray images obtained preoperatively and at 12-month follow-up visit, none of the patients had radiographic signs of patellofemoral OA such as subchondral sclerosis, cystic degeneration, or osteophyte formation. On the other hand, persistent edema of the subchondral bone in patellofemoral joint during the MRI evaluation at 12-month control was detected in 5 knees from Group 1, 3 knees from Group 2, and 9 knees from Group 3 (Table 3) (Fig. 6a). Furthermore, the mean VAS and Lysholm scores of these 17 knees with diagnosed edema or cyst formation on the MRIs were significantly worse than the other knees ($p<0.001$ and $p<0.001$). None of the patients was diagnosed with progressive chondral defect according to MRI scans during the follow-up period. One patient from Group 2 had intra-articular adhesions detected at 12-month MRI control (Fig. 6b).

The overall complication rate of the present study was 3.2% (2 knees out of 61). One patient had superficial

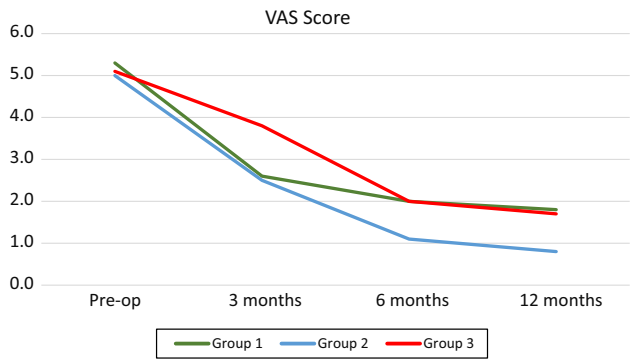

Fig. 3 Graph demonstrating the VAS score changes

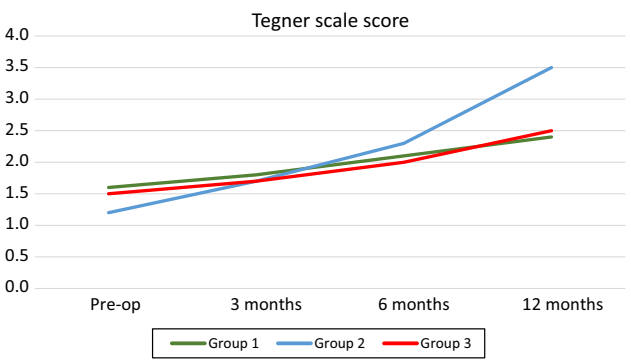

Fig. 5 Graph demonstrating the Tegner score changes

Table 3 MRI evaluation of the operated knees at 12-month follow-up

Variables	Group 1 (*n*)	Group 2 (*n*)	Group 3 (*n*)
Subchondral bone of the patellofemoral joint			
Intact	17	15	12
Edema	5	3	9
Intra-articular adhesions			
No	22	17	21
Yes	0	1	0
Intra-articular effusion			
No	19	16	17
Yes	3	2	4

infection in the form of cellulitis 2 days after surgical intervention in Group 2, and it was treated via the administration of antibiotics and primary wound care without need for secondary surgery. One patient from Group 3 had complex regional pain syndrome which was treated successfully by physiotherapy department. We did not observe any septic arthritis, deep venous thrombosis, pulmonary embolism, or neurovascular complication.

Discussion

The most important findings of the present study were that the application of PRP during ACL reconstruction in patients with concomitant Outerbridge grade 2 patellofemoral cartilage lesion revealed better and durable clinical results, faster early-term healing, and earlier return to previous level of activity with respect to the intra-articular HA injection or no additional treatment. Wide variety in the success rates as well as the clinical and radiographic outcomes has remained as the major controversy regarding cartilage regeneration [2]. Several studies focused on the treatment of full-thickness chondral defects exist in the literature; however, the clinical importance, prognosis, and specific treatment for Outerbridge grade 1 or 2 chondral lesions have been controversial [15, 16, 23]. Secondary or concomitant cartilage lesions in ACL-deficient knee may play a crucial role as not only a potential factor negatively affecting the healing process at short term after surgical reconstruction in the means of individual's functional capacity but also a predisposing factor for the accelerated progression to premature degenerative arthritis. Although ACL injury and reconstruction have been reported as well-established risk factors for the development of tibiofemoral joint OA, patellofemoral degeneration accompanying or secondary to ACL reconstruction has gone largely unrecognized [6]. Most patellofemoral problems, despite being of mild severity after ACL reconstruction, may still have important implications regarding pain and function after surgery. Risberg et al. emphasized that strategies early after ACL injury to prevent the post-traumatic degeneration should be developed because we could not afford to "sit and wait" until knee OA became obvious [17]. Therefore, the present study evaluated the effectiveness of 2 different treatment options applied specifically for Outerbridge grade 2 patellofemoral cartilage lesions accompanying ACL rupture.

Emerging scientific research has been seeking to advance surgical techniques to achieve predictable outcomes via single-stage procedures with durable repair tissue for the surgical treatment of ACL rupture as well as the concomitant intra-articular pathologies. Various noninvasive treatment options such as glucosamine–chondroitin sulfate,

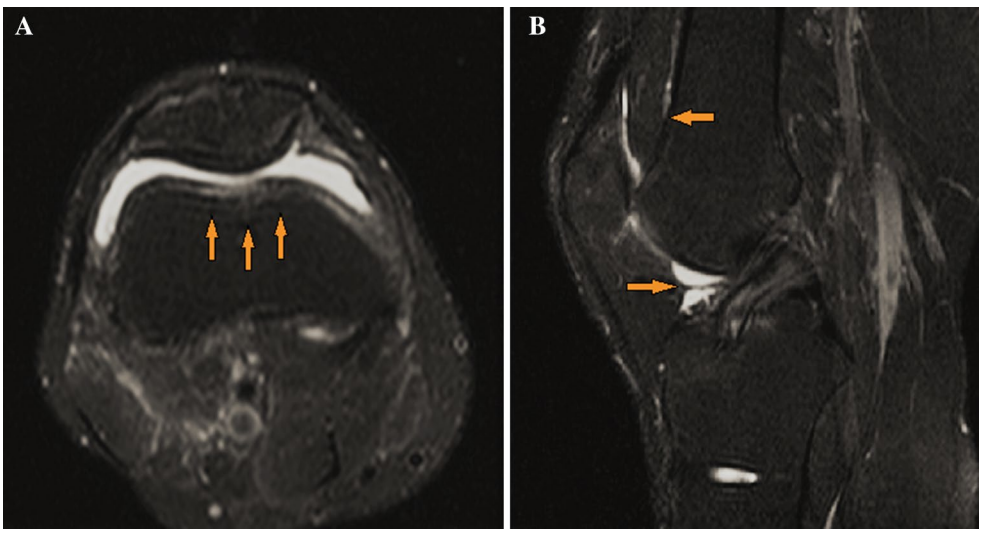

Fig. 6 **a** Persistent subchondral edema of the patellofemoral joint (arrows) at 12-month follow-up. **b** Intra-articular adhesive band formation (arrow) and suprapatellar synovitis (arrow) at 12-month follow-up

intra-articular HA injection, and PRP have been proposed for pain management and modification of the course of cartilage lesions to improve function [11]. Intra-articular HA is a synthetically manufactured product widely used in clinical practice with good results reported in the literature [25]. The use of autologous blood products, such as PRP, was reported as providing an opportunity to improve patient outcomes using an autologous biological alternative while also addressing the underlying inflammation through the stimulation of growth factors and the suppression of inflammatory cytokines [4]. Cole et al. demonstrated no difference between HA and PRP in patients with various grades of OA at any time point in the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain score; however, significant improvements were observed in other patient-reported outcome measures, with their results favoring PRP over HA [4]. The major handicap of this study was the inclusion of patients with different stages of OA varying from grade 1 to 4 classified according to Kellgren–Lawrence. It is strongly predictable that the ones with low-grade or early degenerative arthritis could benefit from such interventions more than the patients with high grade or late stage OA. Kon et al. concluded that autologous PRP injections demonstrated more and longer efficacy than HA injections in reducing pain and symptoms as well as recovering articular function with better results were observed in younger and more active patients who had a low degree of cartilage degeneration [11]. Campbel et al. mentioned that intra-articular PRP was a viable treatment with the potential to lead to symptomatic relief for up to 12 months [3]. The findings of the present study were consistent with the results reported by both Kon et al. and Campbell et al. Although the mean VAS and Lysholm scores at 3-month follow-up were better in the patients treated with either HA or PRP for grade 2 patellofemoral cartilage lesion during ACL reconstruction than the ones who did not receive any specific treatment except the ACL surgery, the efficacy of intra-articular PRP on healing process regarding progression of the mean VAS and Lysholm scores through 3-, 6-, and 12-month follow-ups was significantly better and longer than HA. In other words, the efficacy of intra-articular HA injection was limited to a short time period and thus, transient in such cases.

Typical radiographic findings of patellofemoral OA on X-ray scans become obvious at the late stages of the degenerative process. Nevertheless, none of the patients had any radiographic signs of patellofemoral OA at 12-month postoperative follow-up. Therefore, more sensitive methods such as MRI to detect changes in articular cartilage may provide valuable insight into onset and progression of patellofemoral pathologies [6]. Persistent bone marrow edema-like signal intensity on MRI was reported as frequently present in patients after surgical treatment of osteochondral lesions and may postoperatively continue for a long time [22]. Marlovits et al. emphasized that they found a statistically significant correlation between the clinical outcome and some of the radiological variables, including the structure of the repair tissue, changes in the subchondral bone, and the signal intensities [13]. Subchondral edema in the patellofemoral joint was also detected in 17 patients of our study population even after 12 months from the surgical intervention. Furthermore, a significant correlation between negative MRI findings and worse clinical outcome scores was observed.

The major limitation of the current study was the retrospective evaluation of prospectively followed patient groups and secondly, the limited number of patients with relatively short follow-up time. On the other hand, comparative evaluation of the effectiveness of 2 well-defined treatment options applied specifically for Outerbridge grade 2 patellofemoral cartilage lesions accompanying ACL rupture during early recovery period in different time intervals after ACL reconstruction as well as the MRI evaluation at 12-month postoperative follow-up was the strengths of our study. As the number of patients was limited, the power of the present study may also be questionable. However, the present study may be a reference for further clinical trials to establish a better understanding of the progress, management, and the potential negative effects of low-grade patellofemoral cartilage lesions in ACL-reconstructed knees.

Conclusion

Intra-articular PRP injection applied as the treatment of concomitant Outerbridge grade 2 chondral lesion in patellofemoral joint during arthroscopic ACL reconstruction revealed better and durable clinical outcomes via decreasing the potentially negative effects of chondral pathology on postoperative healing with respect to HA injection.

Acknowledgements This study has been approved by the institutional review board.

Compliance with ethical standards

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

References

1. Arnoczky SP, Sheibani-Rad S (2013) The basic science of platelet-rich plasma (PRP): what clinicians need to know. Sports Med Arthrosc 21(4):180–185
2. Berta A, Duska Z, Toth F, Hangody L (2015) Clinical experiences with cartilage repair techniques: outcomes, indications, contraindications and rehabilitation. Eklem Hastalik Cerrahisi 26(2):84–96

3. Campbell KA, Saltzman BM, Mascarenhas R, Khair MM, Verma NN, Bach BR, Cole BJ (2015) Does intra-articular platelet rich plasma provide clinically superior outcomes compared with other therapies in the treatment of knee osteoarthritis: a systematic review of overlapping meta-analyses. Arthroscopy 31(11):2213–2221
4. Cole BJ, Karas V, Hussey K, Pilz K, Fortier LA (2017) Hyaluronic acid versus platelet-rich plasma: a prospective double-blind randomized controlled trial comparing clinical outcomes and effects on intra-articular biology for the treatment of knee osteoarthritis. Am J Sports Med 45(2):339–346
5. Cox CL, Huston LJ, Dunn WR et al (2014) Are articular cartilage lesions and meniscus tears predictive of IKDC, KOOS, and Marx activity level outcomes after anterior cruciate ligament reconstruction? A 6-year multicenter cohort study. Am J Sports Med 42(5):1058–1067
6. Culvenor AG, Cook JL, Collins NJ, Crossley KM (2013) Is patellofemoral joint osteoarthritis an under-recognised outcome of anterior cruciate ligament reconstruction? A narrative literature review. Br J Sports Med 47(2):66–70
7. Di Matteo B, Filardo G, Kon E, Marcacci M (2015) Platelet-rich plasma: evidence for the treatment of patellar and Achilles tendinopathy—a systematic review. Musculoskelet Surg 99(1):1–9
8. Gao B, Cordova ML, Zheng N (2012) Three-dimensional joint kinematics of ACL-deficient and ACL-reconstructed knees during stair ascent and descent. Hum Mov Sci 31(1):222–235
9. Kato Y, Maeyama A, Lertwanich P et al (2013) Biomechanical comparison of different graft positions for single-bundle anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 21(4):816–823
10. Kim HS, Seon JK, Jo AR (2013) Current trends in anterior cruciate ligament reconstruction. Knee Surg Relat Res 25:165–173
11. Kon E, Mandebaum B, Buda R, Filardo G, Delcogliano M, Timoncini A, Fornasari PM, Giannini S, Marcacci M (2011) Platelet-rich plasma intra-articular injection versus hyaluronic acid viscosupplementation as treatments for cartilage pathology: from early degeneration to osteoarthritis. Arthroscopy 27(10):1490–1501
12. Madry H, Kohn D, Cucchiarini M (2013) Direct FGF-2 gene transfer via recombinant adeno-associated virus vectors stimulates cell proliferation, collagen production, and the repair of experimental lesions in the human ACL. Am J Sports Med 41:194–202
13. Marlovits S, Singer P, Zeller P, Mandl I, Haller J, Trattnig S (2006) Magnetic resonance observation of cartilage repair tissue (MOCART) for the evaluation of autologous chondrocyte transplantation: determination of interobserver variability and correlation to clinical outcome after 2 years. Eur J Radiol 57:16–23
14. Mascarenhas R, Cvetanovich GL, Sayegh ET, Verma NN, Cole BJ, Bush-Joseph C, Bach BR Jr (2015) Does double-bundle anterior cruciate ligament reconstruction improve postoperative knee stability compared with single-bundle techniques? A systematic review of overlapping meta-analyses. Arthroscopy 31(6):1185–1196
15. Oussedik S, Tsitskaris K, Parker D (2015) Treatment of articular cartilage lesions of the knee by microfracture or autologous chondrocyte implantation: a systematic review. Arthroscopy 31(4):732–744
16. Panseri S, Russo A, Cunha C, Bondi A, Di Martino A, Patella S, Kon E (2012) Osteochondral tissue engineering approaches for articular cartilage and subchondral bone regeneration. Knee Surg Sports Traumatol Arthrosc 20(6):1182–1191
17. Risberg MA, Grindem H, Øiestad BE (2016) We need to implement current evidence in early rehabilitation programs to improve long-term outcome after anterior cruciate ligament injury. J Orthop Sports Phys Ther 46(9):710–713
18. Robin BN, Jani SS, Marvil SC, Reid JB, Schillhammer CK, Lubowitz JH (2015) Advantages and disadvantages of transtibial anteromedial portal, and outside-in femoral tunnel drilling in single-bundle anterior cruciate ligament reconstruction: a systematic review. Arthroscopy 31(7):1412–1417
19. Røtterud JH, Risberg MA, Engebretsen L, Arøen A (2012) Patients with focal full-thickness cartilage lesions benefit less from ACL reconstruction at 2-5 years follow-up. Knee Surg Sports Traumatol Arthrosc 20(8):1533–1539
20. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Arøen A (2013) Effect of meniscal and focal cartilage lesions on patient-reported outcome after anterior cruciate ligament reconstruction: a nationwide cohort study from Norway and Sweden of 8476 patients with 2-year follow-up. Am J Sports Med 41(3):535–543
21. Sermer C, Devitt B, Chahal J, Kandel R, Theodoropoulos J (2015) The addition of platelet-rich plasma to scaffolds used for cartilage repair: a review of human and animal studies. Arthroscopy 31(8):1607–1625
22. Sofu H, Kockara N, Oner A, Camurcu Y, Issın A, Sahin V (2017) Results of hyaluronic acid-based cell-free scaffold application in combination with microfracture for the treatment of osteochondral lesions of the knee: 2-year comparative study. Arthroscopy 33(1):209–216
23. Sofu H, Yildirim T, Gürsu S, Issin A, Şahin V (2015) Short-term effects of partial meniscectomy on the clinical results of anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 23(1):184–187
24. Takeda K, Hasegawa T, Kiriyama Y, Matsumoto H, Otani T, Toyama Y, Nagura T (2014) Kinematic motion of the anterior cruciate ligament deficient knee during functionally high and low demanding tasks. J Biomech 47(10):2526–2530
25. Vaishya R, Pandit R, Agarwal AK, Vijay V (2017) Intra-articular hyaluronic acid is superior to steroids in knee osteoarthritis: a comparative, randomized study. J Clin Orthop Trauma. 8(1):85–88
26. Vavken P, Fleming BC, Mastrangelo AN, Machan JT, Murray MM (2012) Biomechanical outcomes after bioenhanced anterior cruciate ligament repair and anterior cruciate ligament reconstruction are equal in a porcine model. Arthroscopy 28:672–680