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Comparing the effect of intra-articular injection of Platelet-rich plasma (PRP) with corticosteroids on the treatment of osteonecrosis of the femoral head

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Abstract

Introduction: Osteonecrosis of the femoral head is a common orthopedic problem that mainly affects young people. The main causes of this disease include the use of steroid drugs, some

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medications, and trauma to the joint. According to the Ficot classification, this disease is divided into four stages, and the more advanced the stage, the more extensive intervention is required. In the early stages, methods such as core decompression and the use of platelet-rich plasma (PRP) are recommended to improve the results. This study aims to evaluate and compare the effectiveness of two treatment methods, PRP and corticosteroid injection, in improving the clinical and radiological symptoms of patients with osteonecrosis of the femoral head.

Methods: This is a retrospective case-control study in which patients aged 18 to 70 years with a diagnosis of stage 1 or 2 osteonecrosis of the femoral head based on MRI referred to the orthopedic clinic of Shahid Bahonar Hospital, Kerman, Iran, were studied. Based on the treatment received, the patients were categorized into two groups: PRP injection and corticosteroid injection. Patients will be evaluated using MRI, modified Kerboul angle, Harris Hip Score, Foot Health Questionnaire (FSHQ-Br), and McGill Pain Questionnaire (MPQ) at specific time intervals. The results will be analyzed using statistical tests and the significance level is considered less than 0.05.

Results: 64 patients with osteonecrosis of the femoral head participated in this study. This study showed that both PRP and corticosteroids are effective in improving symptoms and function in patients with osteonecrosis of the femoral head, although PRP had better long-term results. Corticosteroids showed more immediate pain relief and improved function in the short term (3 months), while PRP provided more sustained improvement in all evaluated outcomes at 6 months. In addition, PRP showed a significant reduction in radiological progression of osteonecrosis compared with corticosteroids. These findings are consistent with the existing evidence of beneficial effects of PRP on angiogenesis, osteogenesis, and inhibition of inflammation in the treatment of osteonecrosis of the femoral head.

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Conclusion: The results of this study indicated that the selection of optimal treatment should be based on a comprehensive assessment of each patient's clinical status, preferences, and treatment goals. Overall, PRP may be a promising treatment option to improve outcomes and quality of life in patients with osteonecrosis of the femoral head.

Keywords: Platelet-rich plasma, PRP, corticosteroids, osteonecrosis, femoral head.

1. Introduction

The femur is the strongest long bone in the body and the main weight-bearing structure of the lower limb. Its fractures, caused by high-energy accidents in young people or co-energetic blows in the elderly, are considered common and important orthopedic injuries. The prevalence of these fractures is increasing with the aging of the population and the modernization of societies, and if treated inappropriately, they are accompanied by complications such as limb shortening and deformity, which reduce the quality of life [1-3].

Avascular necrosis of the femoral head (ONFH) is a common and challenging problem in orthopedic patients, the treatment of which is controversial, especially in the early stages. Patients are usually young and hip replacement at this age has problems and limitations [4]. Common causes of this disease include steroid use, divers' disease, some medications, and direct blows to the joint [5].

According to the Ficat classification, ONFH has four stages; in the early stages, symptoms are mild and limited to changes in bone scan, and in more advanced stages, destruction of the femoral head and acetabulum is seen, and joint replacement or fixation is required. Treatment is more widely agreed upon in advanced stages, but in the early stages the choice of method is debated [6, 7].

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Initial treatment methods include drilling and the use of bone grafts and core decompression, which is the most common conservative method but is associated with limited success and controversial efficacy. This method only reduces intraosseous pressure and does not have a sufficient effect on the healing of necrotic bone [8, 9].

In this regard, the use of platelet-rich plasma (PRP) has been considered as a restorative and auxiliary method. PRP is prepared from the patient's own blood and contains growth factors and cytokines that help accelerate bone and soft tissue healing. The wide range of applications of PRP in orthopedics includes the treatment of non-union of fractures, tendinopathy, ligament injuries, and osteoarthritis [10, 11]. PRP is prepared by centrifuging blood and increasing the concentration of platelets and contains important proteins and growth factors such as TGF-β, PDGF, FGF, and VEGF, which play a role in tissue repair and stem cell activation. This procedure is generally safe and has no major side effects, although there are problems in standardizing its preparation that can affect treatment outcomes [12, 13].

The clinical use of PRP has increased since the early 2000s, and evidence suggests that it can help reduce pain and stop the progression of ONFH. Given the prevalence and complications of ONFH and the variety of treatment options, no method has been definitively proven to be superior [14, 15]. Therefore, the present study compared the effects of intra-articular PRP and corticosteroid injections in patients with ONFH to provide a better treatment option for this disease.

2. Materials and methods

2. 1. Study Type and Population

The present study is a retrospective case-control study that aimed to compare the effect of platelet-rich plasma (PRP) injection with corticosteroids in the treatment of osteonecrosis of the femoral

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head. Patients were not prospectively randomized; rather, they were grouped according to the treatment they had received during routine clinical care. This study was conducted on a group of patients referred to the orthopedic clinic of Shahid Bahonar Hospital, Kerman, Iran, during the period of April to March 2023 with osteonecrosis of the femoral head, whose diagnosis was confirmed by MRI and plain radiography.

2. 2. Inclusion and Exclusion Criteria

2. 2. 1. Inclusion Criteria:

2. 2. 1. 1. Patients with stage 1 or 2 osteonecrosis of the femoral head based on

2. 2. 1. 2. MRI

2. 2. 1. 3. Ages 18 to 70 years

2. 2. 1. 4. Normal bone marrow function (absolute neutrophil count > 1500/mL)

2. 2. 1. 5. Confirmation of osteonecrosis of the femoral head based on clinical and radiographic examinations

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2. 2. 1. 6. No concurrent diagnosis of osteomyelitis

2. 2. 2. Exclusion Criteria:

2. 2. 2. 1. Pregnant women

2. 2. 2. 2. Active infection, HIV, hepatitis B or C, syphilis

2. 2. 2. 3. Active bisphosphonate therapy

2. 2. 2. 4. Uncontrolled diabetes (HbA1c > 8%), peripheral neuropathy, or vascular problems

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2. 2. 2. 5. Receiving hematopoietic growth factors or antiangiogenic products

2. 2. 2. 6. Femoral head collapse on preoperative imaging

2. 3. Group Division and Treatment Method

After recording the information and selecting the treatment method by the patients, they were categorized into two groups based on the treatment received: PRP injection and corticosteroid injection. All injections were performed intra-articularly under fluoroscopic guidance to ensure accurate intra-articular delivery, and all procedures were carried out by a single experienced orthopedic surgeon to minimize inter-operator variability. PRP injection was performed using 60 ml of venous blood collected from the patient, from which 6 ml of PRP was extracted after centrifugation for 15 minutes [16]. In the corticosteroid group, a single intra-articular injection of triamcinolone acetonide (40 mg/mL, 2 mL) was administered under fluoroscopic guidance using the same standardized approach as the PRP group.

2. 4. Imaging Evaluation

MRI imaging was performed before treatment and 6 months after injection to assess changes in the size of the necrotic lesion. The severity of femoral head involvement was assessed based on the modified Kerboul score, which measured the angle of necrosis on midcortical and midsagittal images, and patients were categorized according to the following grades [17]:

Grade 1: less than 200 degrees

Grade 2: 200 to 249 degrees

Grade 3: 250 to 299 degrees

Grade 4: greater than 300 degrees

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2. 5. Clinical Evaluation

Patients were clinically evaluated using the Harris Hip Score, with zero indicating the worst performance and 100 indicating the best performance [18]. Leg health status was also assessed using the FSHQ-Br questionnaire and pain severity using the McGill Pain Questionnaire (MPQ) at three and six months after treatment. The average follow-up period for patients was about one year (from one to two years).

FSHQ-Br questionnaire: It includes 29 questions in three areas of leg pain, function, and general health, and has good validity in Iranian studies.

MPQ questionnaire: It is a standard tool for measuring the quantity and quality of pain in chronic patients, which includes 78 descriptive words in four scales.

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2. 6. Data Analysis

The collected data were analyzed using SPSS version 22. The Kruskal-Wallis non-parametric test and Dunn's post hoc multiple comparison test were used to compare pre- and post-treatment values. The significance level was considered to be less than 0.05.

2. 7. Ethical considerations

The study was conducted with the approval of the Ethics Committee of Kerman University of Medical Sciences, Iran (Ethics Code: IR.KMU.AH.REC.1403.181), and all participants signed an informed consent form. Confidentiality of information and adherence to ethical principles were mandatory at all stages of the research. Participation in the study and continued cooperation were voluntary based on the consent of the individuals, and all activities were carried out within the

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framework of professional qualifications. The objectives of the study were explained to the participants and the center officials, and the rights of the patients were respected.

3. Results

3. 1. Demographic and baseline characteristics

In this study, 64 patients with osteonecrosis of the femoral head were included and categorized into two treatment groups based on the treatment they had received, including 32 in the PRP group and 32 in the corticosteroid group. Demographic and baseline characteristics such as age, gender, and disease stage were similar between the two groups, and no significant statistical difference was observed, indicating the homogeneity of the two groups and the comparability of the results (Table 1).

Table 1. Demographic and baseline characteristics of patients.

Characteristics	PRP group (n=32)	Corticosteroid group (n=32)	P-value
Age (years)	45.6±8.2	47.1±7.9	0.45
Gender (male/female)	14/18	12/20	0.61
Stage of osteonecrosis (1/2)	18/14	16/16	0.62

3. 2. MRI Results

The modified Kerboul angle was measured on MRI to determine the extent of femoral head involvement. After 3 months, there was no significant difference in this angle between the two groups ($P>0.05$). However, at 6 months after treatment, the PRP group showed a significantly

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lower Kerboul angle than the corticosteroid group, indicating a better effect of PRP in reducing disease progression over time (P<0.05) (Table 2).

Table 2: MRI Results (Modified Kerboul Angle).

Time	PRP group (n=32)	Corticosteroid group (n=32)	P-value
Baseline	250.4±16.6	248.7±14.9	0.66
3 months	235.2±16.1	239.5±15.4	0.28
6 months	220.8±15.8	232.6±16.3	0.005

3. 3. Clinical Results

3. 3. 1. Harris Hip Score

At baseline, there was no significant difference in the performance scores of the two groups. Both groups had significant improvement in the Harris Hip Score after 3 and 6 months (P<0.05), but there was no difference between the two groups (P>0.05) (Table 3).

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Table 3: The Harris Hip Score.

Time	PRP group (n=32)	Corticosteroid group (n=32)	P-value
Baseline	52.4±5.8	54.1±7.8	0.41
3 months	68.2±9.1	70.5±8.6	0.31
6 months	80.6±8.9	75.3±9.4	0.002

3. 3. 2. Foot Health Questionnaire (FSHQ-Br)

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In the first 3 months, the corticosteroid group showed a better score on this questionnaire, which was related to less pain and better foot function (P<0.05). However, at 6 months, the PRP group showed significant improvement and higher scores than the corticosteroid group (P<0.05) (Table 4).

Table 4: Foot Health Status Questionnaire (FSHQ-Br) score.

Time	PRP group (n=32)	Corticosteroid group (n=32)	P-value
Baseline	38.5±6.2	40.1±5.9	0.29
3 months	52.3±7.1	58.6±6.5	0.0007
6 months	68.9±6.8	61.4±7.2	0.0001

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3. 3. 3. McGill Pain Questionnaire (MPQ)

Similar results were reported regarding pain intensity; At 3 months, pain was less in the corticosteroid group (P<0.05), but at 6 months, less pain was reported by patients in the PRP group (P<0.05) (Table 5).

Table 5: The McGill Pain Questionnaire (MPQ) scores.

Time	PRP group (n=32)	Corticosteroid group (n=32)	P-value
Baseline	28.4±4.6	29.2±4.3	0.47
3 months	20.5±4.1	17.3±3.8	0.002
6 months	12.7±3.5	16.8±3.9	0.0001

3. 4. Subgroup analysis

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Analysis by age (<50 years and 50 years or older) and gender showed that the treatment efficacy was not significantly different in these subgroups (P>0.05). Also, stage 1 osteonecrosis patients in both treatment groups had better improvement in functional scores, foot health, and pain than stage 2, although this difference was not statistically significant.

3. 5. Safety and adverse events

No serious adverse events were reported during the 6-month follow-up period. In the PRP group, 3 patients (9.4%) had mild to moderate pain, and 2 patients (6.3%) had transient joint stiffness. In the corticosteroid group, 4 patients (12.5%) experienced pain, 3 patients (9.4%) had joint stiffness, and 1 patient (3.1%) had injection site swelling. All of these symptoms resolved spontaneously within 1 to 2 weeks. No cases of infection, allergic reaction, or fracture were observed in either group, confirming the safety of both treatments.

Overall, both PRP and corticosteroid treatments resulted in significant improvement in patients' symptoms and function. Corticosteroids provided faster pain relief and improved function in the short term (3 months), but PRP was associated with a significant reduction in osteonecrosis progression, pain, and function in the long term (6 months). This evidence suggests that PRP, due to its anti-inflammatory, angiogenic, and osteogenic properties, may be a more effective option for managing this disease over time.

Physicians should consider the clinical characteristics of patients and the advantages and disadvantages of each method to select the optimal treatment and conduct the decision-making process in collaboration with patients. Also, careful monitoring and continuous follow-up of patients is essential to assess response to treatment and adjust treatment plans. Future studies with

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larger samples and longer follow-up periods can clarify the role of PRP in the treatment of osteonecrosis of the femoral head and make this method a safer and more effective option.

4. Discussion

The results of this study showed that both intra-articular injection of platelet-rich plasma (PRP) and corticosteroids are effective in improving symptoms and function in patients with osteonecrosis of the femoral head. In the short term (3 months), the corticosteroid group showed significant improvements in the Foot Health Questionnaire (FSHQ-Br) and McGill Pain Questionnaire (MPQ) scores, indicating faster pain relief and improved leg function compared with the PRP group. However, at the 6-month assessment, the PRP group showed greater improvement in all evaluated outcomes, including the Harris hip score, FSHQ-Br score, and MPQ score. In addition, MRI imaging showed that the PRP group had a significant reduction in the modified Kerboul angle after 6 months, indicating less progression of osteonecrosis compared with the corticosteroid group. Both interventions were well tolerated, and no serious adverse events were reported. Subgroup analysis showed that the efficacy of the treatment was not affected by age, gender, or stage of disease.

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Our results are consistent with the findings of previous studies that support PRP as a promising treatment option for patients with osteonecrosis of the femoral head. In a systematic review, Jun Han et al. found that PRP treats osteonecrosis of the femoral head mainly by inducing angiogenesis and osteogenesis, inhibiting inflammation, and preventing glucocorticoid-induced apoptosis. They also showed that PRP as an adjunct therapy to core decompression, especially when combined with stem cells and bone grafting, shows promising results in improving the treatment of patients with early-stage osteonecrosis of the femoral head. These findings are consistent with the results

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of our study that PRP is more effective in reducing the progression of osteonecrosis and improving clinical outcomes compared with corticosteroids [19].

Other studies also support the use of PRP for the treatment of osteonecrosis of the femoral head in combination with other interventions. Wang et al. [20] reported that the combined use of clot-releasing platelet-rich plasma and allogeneic human umbilical cord mesenchymal stem cells showed promising therapeutic results in the treatment of glucocorticoid-induced osteonecrosis of the femoral head. They suggested that this combined approach may provide important insights into intra-articular therapy and pave the way for future clinical management of osteonecrosis of the femoral head. These findings are consistent with our results suggesting the potential benefits of PRP in improving long-term outcomes in patients with osteonecrosis of the femoral head.

However, a recent systematic review by Ning Liu et al. [21] found that there is insufficient evidence to draw definitive conclusions about the effectiveness of PRP in the treatment of osteonecrosis of the femoral head. They noted that most of the available studies have limitations in terms of design, sample size, and follow-up duration. Therefore, they recommended conducting high-quality randomized clinical trials to address these knowledge gaps. Similarly, our study also had some limitations, including a small sample size and lack of blinding. Therefore, the interpretation of the results should be done with caution, and further research is needed to confirm these findings.

In the following discussion, we can mention the effect of PRP on the molecular pathways involved in the pathophysiology of osteonecrosis of the femoral head. PRP contains a wide range of growth factors and cytokines that play an important role in regulating cell proliferation, differentiation, migration, and angiogenesis [22]. For example, platelet-derived growth factor (PDGF) and transforming growth factor-beta (TGF-β) present in PRP can induce osteoblast proliferation and

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differentiation, while vascular endothelial growth factor (VEGF) and basic fibroblast growth factor (bFGF) can stimulate angiogenesis, which can contribute to bone remodeling and improve blood supply to the damaged area, which is necessary for reversing the process of osteonecrosis [23].

In addition, there is evidence that PRP can inhibit inflammation at the site of osteonecrosis. Inflammation plays an important role in the progression of osteonecrosis of the femoral head, leading to destruction of the bone matrix and death of osteocytes.

Zheng et al. [24] demonstrated that PRP can reduce the expression of proinflammatory cytokines such as interleukin-1 beta (IL-1β) and tumor necrosis factor alpha (TNF-α) while increasing anti-inflammatory factors such as interleukin-10 (IL-10). These findings suggest that the anti-inflammatory properties of PRP may play a role in reducing tissue damage and facilitating bone healing in osteonecrosis of the femoral head. Despite the promising results of the present study and the available evidence, several aspects of the use of PRP in the treatment of osteonecrosis of the femoral head require further investigation. First, the optimal formulation of PRP, including the ideal platelet concentration and growth factor ratio, remains unclear. Future studies should establish standardized protocols for the preparation of PRP to maximize efficacy and reproducibility. Second, the optimal dosing regimen of PRP, including the number of injections and the interval between treatments, should be further investigated. Third, it is necessary to compare PRP with other emerging therapies such as cell therapy and bone grafting to determine its relative place in the management of osteonecrosis of the femoral head. Finally, the long-term outcomes of PRP treatment in patients with osteonecrosis of the femoral head are uncertain. Although our study showed that PRP has better results compared with corticosteroids at 6-month follow-up, longer studies are needed to assess the sustainability of these effects and the impact on long-term disease progression.

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In a prospective study with a median follow-up of 5 years, Palma Alvarado et al. found that PRP injection combined with core decompression could prevent disease progression and delay the need for total hip replacement surgery [25].

However, further randomized controlled clinical trials with longer follow-up periods are needed to confirm these findings and fully elucidate the potential of PRP in modifying the natural course of osteonecrosis of the femoral head. Despite these limitations, our results provide preliminary evidence regarding the potential efficacy and safety of PRP compared with corticosteroids for the treatment of osteonecrosis of the femoral head. Based on the observed reduction in modified Kerboul angle progression at 6 months, PRP appears to act not merely as a symptomatic agent but as a potentially disease-modifying intervention. The biological rationale for this effect lies in PRP's capacity to promote angiogenesis via VEGF, support osteogenesis through TGF-β and PDGF, and suppress local inflammatory mediators, collectively addressing the underlying pathophysiology of osteonecrosis rather than its symptoms alone. In contrast, corticosteroids, while providing faster symptomatic relief, carry a known risk of contributing to osteonecrosis when used systemically; their short-term intra-articular benefit in this context is primarily anti-inflammatory and analgesic. Given the relative advantages of PRP in improving long-term outcomes, it may be a preferred treatment option for patients seeking more stable results. However, corticosteroid treatment may be more appropriate for patients requiring immediate symptomatic relief. Ultimately, the selection of the optimal treatment should be based on a careful assessment of the patient's clinical status, preferences, and treatment goals. Shared decision-making between physicians and patients is essential to achieve the best outcomes.

5. Conclusion

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The findings of this study support PRP as an effective and safe treatment option for patients with early-stage osteonecrosis of the femoral head. Compared with corticosteroids, PRP showed better results in reducing the progression of osteonecrosis and improving patients' long-term function. However, given the limitations of this study, further research with a more robust design and larger patient population is needed to confirm these findings and determine the long-term efficacy and safety of PRP in this patient population. By doing so, PRP may emerge as a promising treatment strategy to improve outcomes and quality of life in patients with osteonecrosis of the femoral head.

References

1. Deepak M, K Jain, K A Rajamanya, P R Gandhi, C Rupakumar, and R Ravishankar (2012) Functional outcome of diaphyseal fractures of femur managed by closed intramedullary interlocking nailing in adults. Annals of African medicine 11.
2. Fischer H, T Maleitzke, C Eder, S Ahmad, U Stöckle, and K Braun (2021) Management of proximal femur fractures in the elderly: current concepts and treatment options. European journal of medical research 26:86.
3. Chang S-M, Z-Y Hou, S-J Hu, and S-C Du (2020) Intertrochanteric femur fracture treatment in Asia: what we know and what the world can learn. Orthopedic Clinics 51:189-205.
4. Agarwala S, D Jain, V Joshi, and A Sule (2005) Efficacy of alendronate, a bisphosphonate, in the treatment of AVN of the hip. A prospective open-label study. Rheumatology 44:352-359.
5. Agarwala S, A Sule, B Pai, and V Joshi (2002) Alendronate in the treatment of avascular necrosis of the hip. Rheumatology 41:346-347.
6. Bozic K J, D Zurakowski, and T S Thornhill (1999) Survivorship analysis of hips treated with core decompression for nontraumatic osteonecrosis of the femoral head. JBJS 81:200-209.

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7. Cheng E Y, I Thongtrangan, A Laorr, and K J Saleh (2004) Spontaneous resolution of osteonecrosis of the femoral head. JBJS 86:2594-2599.

8. Gangji V, V De Maertelaer, and J-P Hauzeur (2011) Autologous bone marrow cell implantation in the treatment of non-traumatic osteonecrosis of the femoral head: five year follow-up of a prospective controlled study. Bone 49:1005-1009.

9. Tabatabaee R M, S Saberi, J Parvizi, S M J Mortazavi, and M Farzan (2015) Combining concentrated autologous bone marrow stem cells injection with core decompression improves outcome for patients with early-stage osteonecrosis of the femoral head: a comparative study. The Journal of arthroplasty 30:11-15.

10. Andersen C, N M Wragg, M Shariatzadeh, and S L Wilson (2021) The use of platelet-rich plasma (PRP) for the management of non-union fractures. Current osteoporosis reports 19:1-14.

11. Laver L, N Marom, L Dnyanesh, O Mei-Dan, J Espregueira-Mendes, and A Gobbi (2017) PRP for degenerative cartilage disease: a systematic review of clinical studies. Cartilage 8:341-364.

12. Kaux J-F, M Bouvard, C Lecut, C Oury, A Gothot, M Sanchez, and J-M Crielaard (2015) Reflections about the optimisation of the treatment of tendinopathies with PRP. Muscles, Ligaments and Tendons Journal 5:1.

13. Kaux J-F, V Libertiaux, J-L Croisier, and J-M Crielaard (2016) Platelet-rich plasma (PRP) to treat chronic patellar tendinopathies: comparison of a single versus two closely-timed injections. Muscles, Ligaments and Tendons Journal 5:297.

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14. Zalavras C G and J R Lieberman (2014) Osteonecrosis of the femoral head: evaluation and treatment. JAAOS-Journal of the American Academy of Orthopaedic Surgeons 22:455-464.

15. Hall M P, P A Band, R J Meislin, L M Jazrawi, and D A Cardone (2009) Platelet-rich plasma: current concepts and application in sports medicine. JAAOS-Journal of the American Academy of Orthopaedic Surgeons 17:602-608.

16. Houdek M T, C C Wyles, M S Collins, B M Howe, A Terzic, A Behfar, and R J Sierra (2018) Stem cells combined with platelet-rich plasma effectively treat corticosteroid-induced osteonecrosis of the hip: a prospective study. Clinical Orthopaedics and Related Research® 476:388-397.

17. Ha Y-C, W H Jung, J-R Kim, N H Seong, S-Y Kim, and K-H Koo (2006) Prediction of collapse in femoral head osteonecrosis: a modified Kerboul method with use of magnetic resonance images. JBJS 88:35-40.

18. Harris W H (1969) Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty: an end-result study using a new method of result evaluation. JBJS 51:737-755.

19. Han J, F Gao, Y Li, J Ma, W Sun, L Shi, X Wu, and T Li (2020) The use of platelet-rich plasma for the treatment of osteonecrosis of the femoral head: a systematic review. BioMed Research International 2020:2642439.

20. Wang Y, S Luan, Z Yuan, S Wang, S Fan, C Ma, and S Wu (2022) The Combined Use of Platelet-Rich Plasma Clot Releasate and Allogeneic Human Umbilical Cord Mesenchymal Stem Cells Rescue Glucocorticoid-Induced Osteonecrosis of the Femoral Head. Stem Cells International 2022:7432665.

ARTICLE IN PRESS

ARTICLE IN PRESS

21. Liu N, C Zheng, Q Wang, and Z Huang (2022) Treatment of non-traumatic avascular necrosis of the femoral head. Experimental and therapeutic medicine 23:321.

22. Alsousou J, M Thompson, P Hulley, A Noble, and K Willett (2009) The biology of platelet-rich plasma and its application in trauma and orthopaedic surgery: a review of the literature. The Journal of Bone & Joint Surgery British Volume 91:987-996.

23. Eppley B L, J E Woodell, and J Higgins (2004) Platelet quantification and growth factor analysis from platelet-rich plasma: implications for wound healing. Plastic and reconstructive surgery 114:1502-1508.

24. Marker D R, T M Seyler, S D Ulrich, S Srivastava, and M A Mont (2008) Do modern techniques improve core decompression outcomes for hip osteonecrosis? Clinical orthopaedics and related research 466:1093-1103.

25. Vives J M M, M Jornet-Gibert, J Cámara-Cabrera, P L Esteban, L Brunet, L Delgado-Flores, P Camacho-Carrasco, P Torner, and F Marcano-Fernández (2020) Mortality rates of patients with proximal femoral fracture in a worldwide pandemic: preliminary results of the Spanish HIP-COVID observational study. JBJS 102:e69.

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