

ORIGINAL RESEARCH

Clinical Outcomes and Exploratory MRI T2 Mapping Findings Following Platelet-Rich Plasma Injections in Patients with Knee Osteoarthritis: A Retrospective Case Series

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ABSTRACT

This study aimed to assess clinical outcomes and exploratory MRI T2 mapping changes following platelet-rich plasma (PRP) injections in patients with knee osteoarthritis (OA). This retrospective case series included 47 patients with Kellgren–Lawrence stage 2–3 knee osteoarthritis who underwent intraarticular PRP injection and were followed for 6 months. Clinical outcomes, including pain (VAS), functional status (WOMAC), quality of life (SF-36), knee range of motion (flexion), and the Timed Up and Go test, were obtained from medical records before and after treatment. Magnetic resonance imaging (MRI) T2 mapping of the meniscus was also analyzed. At 6 months, significant improvements were observed in VAS, WOMAC, SF-36 physical function, pain, physical role limitation, social function, and knee flexion ($p<0.05$). No significant changes were found in the Timed Up and Go test, or several SF-36 subdomains. MRI T2 mapping showed a decrease in T2 relaxation time in the medial meniscus anterior horn ($p=0.047$); however, this finding did not remain statistically significant after Bonferroni correction for multiple comparisons (Bonferroni-adjusted $p=0.188$). PRP injections were associated with improvements in pain, functional outcomes, and selected quality-of-life parameters in patients with knee OA. MRI T2 mapping findings should be considered exploratory and do not provide conclusive evidence of meniscal tissue repair or regeneration. Furthermore, due to the retrospective design and lack of a control group, a causal relationship cannot be established. Prospective controlled studies are required to confirm these findings.

Keywords: Osteoarthritis. Knee. Platelet-Rich Plasma. Injections. Intra-Articular. Magnetic Resonance Imaging. T2 Mapping. Menisci. Pain. Quality of Life.

Diz Osteoartriti Olan Hastalarda Trombositten Zengin Plazma Enjeksiyonları Sonrası Klinik Sonuçlar ve Keşifsel MRG T2 Haritalama Bulguları: Retrospektif Bir Olgu Serisi

ÖZET

Bu çalışmanın amacı, diz osteoartriti (OA) olan hastalarda trombositten zengin plazma (PRP) enjeksiyonları sonrasındaki klinik sonuçları ve keşifsel MRG T2 haritalama değişikliklerini değerlendirmektir. Bu retrospektif vaka serisine, Kellgren–Lawrence evre 2–3 diz osteoartriti olan ve intraartiküler PRP enjeksiyonu uygulanarak 6 ay takip edilen 47 hasta dahil edildi. Hastaların tedavi öncesi ve 6. ay verileri; ağrı (VAS), fonksiyonel durum (WOMAC), yaşam kalitesi (SF-36), diz eklem hareket açıklığı (fleksiyon) ve Timed Up and Go testi açısından değerlendirildi. Ayrıca menisküs yapısına ait manyetik rezonans görüntüleme (MRG) T2 haritalama ölçümleri analiz edildi. Altıncı ay sonunda VAS, WOMAC, SF-36 fiziksel fonksiyon, ağrı, fiziksel rol kısıtlılığı, sosyal fonksiyon ve diz fleksiyon açısından istatistiksel olarak anlamlı iyileşmeler saptandı ($p<0,05$). Timed Up and Go testi ve bazı SF-36 alt parametrelerinde anlamlı değişiklik izlenmedi. MRI T2 haritalaması, medial menisküs anterior horn T2 relaksasyon süresinde bir azalma gösterdi ($p=0.047$); ancak bu bulgu, çoklu karşılaştırmalar için Bonferroni düzeltmesinden sonra istatistiksel olarak anlamlılığını korumadı (Bonferroni düzeltilmiş p -değeri = 0.188). PRP enjeksiyonları, diz osteoartriti hastalarında ağrı, fonksiyon ve bazı yaşam kalitesi parametrelerinde iyileşme ile ilişkili bulunmuştur. MR T2 haritalama bulguları keşifsel olarak değerlendirilmelidir ve menisküs dokusunun onarımı veya rejenerasyonuna dair kesin kanıt sağlamaz. Ayrıca retrospektif tasarım ve kontrol grubunun olmaması nedeniyle nedensel bir ilişki kurulamaz. Bulguların doğrulanması için prospektif kontrollü çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Diz Osteoartriti. Trombositten Zengin Plazma. Eklem İçi Enjeksiyonlar. Manyetik Rezonans Görüntüleme. T2 Haritalama. Menisküsler. Ağrı. Yaşam Kalitesi.

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Knee pain is one of the most common musculoskeletal complaints encountered in clinical practice, and osteoarthritis (OA) is the most frequent cause of knee pain in the adult population¹. With increasing life expectancy and rising body mass index levels, the prevalence of knee OA has markedly increased over time². OA is a multifactorial disease that involves mechanical stress as well as metabolic and inflammatory processes affecting the articular cartilage, subchondral bone, meniscus, and synovial tissue, ultimately resulting in chondrocyte dysfunction³. Currently, management of knee OA is mainly based on symptom control as disease-modifying treatment options remain limited. Among conservative treatment strategies, intra-articular injections such as hyaluronic acid (HA), corticosteroids, and platelet-rich plasma (PRP) are widely used⁴. PRP is an autologous blood-derived product with a high concentration of platelets and growth factors that may modulate tissue repair, chondrogenesis, and extracellular matrix remodeling⁵. Several studies have demonstrated improvements in pain and functional outcomes following PRP treatment; however, there is conflicting evidence regarding its superiority over other intra-articular therapies⁶⁻⁸.

Some randomized comparative studies suggested that PRP might provide longer pain relief and functional improvement than HA or corticosteroids⁹⁻¹¹. Additionally, meta-analyses have indicated that PRP injections may be more effective than placebo or other injection treatments in improving pain and physical function at different follow-up periods¹². However, other reports suggest that PRP may be beneficial primarily in early-stage OA¹³, while recent reviews point to potential efficacy at different disease stages¹⁴⁻¹⁶. Despite these findings, current clinical guidelines do not provide strong recommendations for the use of PRP, reflecting the ongoing uncertainty in the literature. Beyond clinical outcomes, assessment of structural changes is essential for a more comprehensive evaluation of treatment effects. Magnetic resonance imaging (MRI) T2 mapping has emerged as a non-invasive quantitative technique that

reflects water content and collagen organization in meniscus tissue and enables the detection of early microstructural changes¹⁷.

This study aimed to evaluate the clinical outcomes following intra-articular PRP injections, including pain intensity, functional status, health-related quality of life, knee range of motion, and balance and mobility performance and to investigate potential structural changes using MRI T2 mapping in patients with knee osteoarthritis.

Materials and Methods

Study Design and Participants

This single-center retrospective pre- and post-case series included patients with knee osteoarthritis who received intra-articular PRP injections between September 2018 and September 2019 and completed a six-month follow-up period. The study was approved by the Uludağ University Clinical Research Ethics Committee (approval number: 2020-6/7, date: 15.04.2020) and conducted at the Department of Physical Medicine and Rehabilitation in accordance with the principles of the Declaration of Helsinki.

Medical records of patients aged ≥ 40 years who were diagnosed with knee OA, had radiographic Kellgren–Lawrence stage 2 or 3 disease, received intra-articular PRP injections and had complete baseline and six-month follow-up clinical and MRI data were retrospectively reviewed. Exclusion criteria were inflammatory arthritis, traumatic knee pathology unrelated to OA, previous knee surgery or incomplete follow-up data. A total of 68 patients were initially identified; 21 were excluded based on the predefined exclusion criteria, and the final analysis included 47 patients.

No additional physical therapy interventions, structured exercise programs, or nonsteroidal anti-inflammatory (NSAID) treatment were provided during the study period.

Outcome Measures

Clinical data were obtained from medical records at baseline and at 6 months following PRP treatment. Outcome measures included pain assessed by Visual Analogue Scale (VAS)¹⁸, quality of life assessed by Short Form-36 (SF-36)¹⁹, and functional status assessed by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)²⁰, Knee joint range of motion (flexion) and Timed Up and Go (TUG)²¹ test were also recorded.

MRI T2 Mapping

Available knee MRI scans were analyzed for T2 relaxation times of the meniscus. Quantitative T2

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mapping measurements were performed using a 3D image processing software 3D slicer (version 5.0.2). Measurements were obtained from the anterior and posterior horns of both medial and lateral menisci¹⁷.

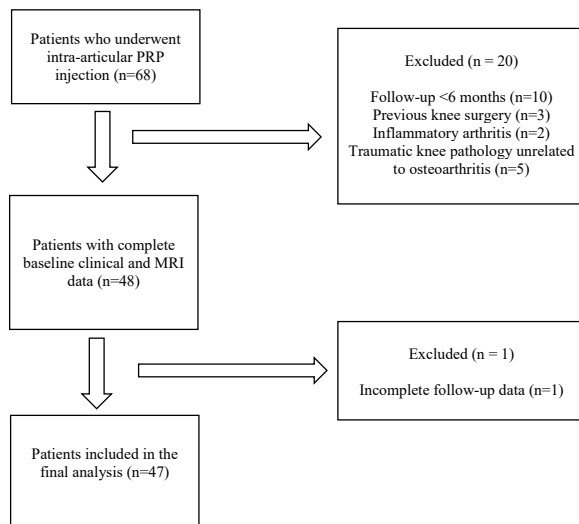


Figure 1:

Flow chart illustrating the identification, eligibility assessment, and inclusion of patients in the retrospective case series.

PRP Preparation and Injection Procedure

PRP was prepared using a commercially available system (Easy PRP kit). Approximately 10 mL of venous blood was collected from each patient and centrifuged in two steps (first at 3000 rpm for 8 minutes and then for 1200 rpm 5 minutes). After separation, approximately 4 mL of PRP containing plasma and buffy coat was obtained. The platelet concentration was reported by the manufacturer to be approximately 1×10^6 platelets/ μ L. Because the buffy-coat layer was included, the preparation was presumed to be leukocyte-rich; however, leukocyte counts were not measured.

Intra-articular injections were administered via the medial parapatellar approach with the patient in a seated position and the knee in flexion, under sterile conditions. Two injections were performed at one-week intervals.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 21.0. Because of the retrospective design, no a priori sample size calculation was performed, and all eligible patients with complete baseline and six-month follow-up data were included. The normality of within-patient change scores was assessed using the Shapiro–Wilk test. Continuous variables were summarized as mean $\pm$ standard deviation or median (minimum–maximum), as

appropriate. Baseline and six-month measurements were compared using the paired-samples t-test or the Wilcoxon signed-rank test, depending on the distribution of within-patient change scores.

Bonferroni correction was applied to the four MRI T2 mapping comparisons involving the anterior and posterior horns of the medial and lateral menisci. Both nominal and Bonferroni-adjusted p-values were reported. Adjusted p-values were calculated as min (nominal p-value $\times$ 4, 1.000). For the MRI analyses, a Bonferroni-adjusted p-value <0.05 , equivalent to a nominal p-value <0.0125 , was considered statistically significant. For all other analyses, two-sided p-values <0.05 were considered statistically significant.

In addition, a sensitivity analysis was conducted under a two-sided paired-samples t-test framework to determine the minimum detectable standardized paired effect size for the available sample size. With 47 paired observations and an alpha level of 0.05, the minimum detectable effect size was $d_z = 0.42$ at 80% power and $d_z = 0.48$ at 90% power.

Results

A total of 68 patients were initially identified; 20 were excluded based on the predefined exclusion criteria, and one additional patient was excluded due to incomplete follow-up data, resulting in a final study population of 47 patients.

The patients had a mean age of 61 ± 5.1 years, a mean symptom duration of 15 ± 3 months, and a mean body mass index (BMI) of 29.9 ± 5.2 kg/m². Most patients were classified as overweight or obese. Baseline demographic and clinical characteristics are presented in Table I.

Table I. Baseline demographic and clinical characteristics of the study population (n=47)

	Value
Age (years)	61 $\pm$ 5.1
BMI (kg/m ²)	29.9 $\pm$ 5.2 kg/m ²
Symptom duration (months)	15 $\pm$ 3
Gender	
Female	39 (83.0)
Male	8 (17.0)
Working status	
Working	17 (36.2)
Not working	30 (63.8)
Education status	
Primary school graduate	23 (48.9)
Secondary school graduate	2 (4.2)
High school graduate	10 (21.3)
University graduate	12 (25.6)
KL staging	
Stage 2	24 (51.1)
Stage 3	23 (48.9)

KL staging: Kellgren Lawrence staging. Data are presented as mean $\pm$ standard deviation, median (interquartile range), or n (%), as appropriate.

At 6 months following PRP injections, statistically significant improvements were observed in several clinical parameters. Pain severity, assessed by VAS, showed a significant reduction ($p<0.001$). Functional status, evaluated by WOMAC, also demonstrated significant improvement ($p=0.001$). In addition, significant improvements were observed in SF-36 subdomains, including physical function ($p=0.002$), physical role limitation ($p<0.001$), pain ($p<0.001$), and social function ($p=0.012$). Knee flexion range of motion increased significantly ($p=0.003$).

No statistically significant changes were detected in Timed Up and Go (TUG) test ($p=0.403$), or in the SF-36 subdomains of general health ($p=0.181$), energy ($p=0.429$), emotional role limitation ($p=0.219$), and mental health ($p=0.880$).

Table II. Changes in clinical and MRI T2 mapping outcomes from baseline to six months after PRP injection

	Before injection	After injection	Nominal p-value	Bonferroni-adjusted p-value
Clinical outcomes				
SF-PF	45.0 (5.0/90.0)	50.0 (0.0/95.0)	0.002	-
SF-PRR	0.0 (0.0/100.0)	50.0 (0.0/100.0)	<0.001	-
SF-P	45.0 (0.0/100.0)	55.0 (0.0/100.0)	<0.001	-
SF-GH	45.0 (0.0/85.0)	50.0 (0.0/95.0)	0.181	-
SF-E	45.0 (10.0/100.0)	50.0 (5.0/100.0)	0.429	-
SF-SF	62.5 (0.0/100.0)	62.5 (12.5/100.0)	0.012	-
SF-ERR	33.3 (0.0/100.0)	66.7 (0.0/100.0)	0.219	-
SF-MH	60.0 (16.0/100.0)	64.0 (32.0/100.0)	0.880	-
Knee flexion	121.3 $\pm$ 13.1	124.8 $\pm$ 10.3	0.003	-
Timed up and go test	11.2 (8.5/27.8)	11.3 (6.9/21.0)	0.403	-
WOMAC	46.0 (13.0/76.0)	33.0 (0.0/87.0)	0.001	-
VAS	5.0 (2.0/10.0)	3.0 (0.0/10.0)	<0.001	-
MRI T2 mapping outcomes				
Lant	38.0 $\pm$ 4.5	38.2 $\pm$ 5.3	0.809	1.000
Lpost	37.0 $\pm$ 3.8	36.0 $\pm$ 4.6	0.307	1.000
Mant	36.5 $\pm$ 5.2	34.6 $\pm$ 5.0	0.047	0.188
Mpost	36.7 $\pm$ 5.8	35.9 $\pm$ 5.7	0.424	1.000

Data are presented as median (minimum–maximum) or mean $\pm$ standard deviation, as appropriate. Nominal p-values are reported for all outcomes. A Bonferroni adjustment was applied only to the four MRI T2 mapping comparisons, resulting in a corrected significance level of $\alpha = 0.0125$. Bonferroni-adjusted p-values were calculated as min (nominal p-value $\times$ 4, 1.000). None of the MRI T2 mapping outcomes remained statistically significant after correction.

SF-36, 36-Item Short Form Health Survey; PF, physical functioning; PRR, physical role restriction; P, bodily pain; GH, general health; E, energy/vitality; SF, social functioning; ERR, emotional role restriction; MH, mental health; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; VAS, Visual Analogue Scale; Lant, anterior horn of the lateral meniscus; Lpost, posterior horn of the lateral meniscus; Mant, anterior horn of the medial meniscus; Mpost, posterior horn of the medial meniscus.

Sensitivity analysis showed that, with 47 paired observations and a two-sided alpha level of 0.05, the study could detect standardized paired effect sizes of $d_z = 0.42$ and $d_z = 0.48$ with 80% and 90% power, respectively.

MRI T2 mapping analysis showed a nominal decrease in T2 relaxation time in the anterior horn of the medial meniscus (nominal $p=0.047$). However, this finding was not statistically significant after Bonferroni correction (Bonferroni-adjusted $p=0.188$). None of the four MRI T2 mapping outcomes remained statistically significant after correction.

Detailed pre- and post-treatment values of clinical and radiological parameters are presented in Table II.

No major complications or infections associated with PRP injection were observed during the six-month follow-up period. Five patients experienced transient synovitis with relevant mild knee swelling and knee pain following the injection; none required joint aspiration or additional intervention. All symptoms resolved with local ice application, and no persistent adverse events were reported.

Discussion and Conclusion

In this retrospective study, we evaluated clinical and MRI outcomes following intra-articular PRP injections in patients with Kellgren–Lawrence stage 2–3 knee osteoarthritis. At 6 months, improvements were observed in pain, functional scores, and selected domains of quality of life. However, given the retrospective design and the absence of a control group, these findings should be interpreted as associations rather than evidence of a causal treatment effect.

The observed reductions in VAS and WOMAC scores, increase in knee flexion degree along with improvements in SF-36 physical domains, are generally consistent with previous studies reporting symptomatic benefits of PRP in knee OA. PRP is considered a biologically active product that may influence tissue repair processes through growth factors affecting chondrocyte activity and mesenchymal stem cell proliferation^{22–24}. PRP and HA had similar results at 6 months in a meta-analysis of randomized controlled trials, but PRP was superior at longer follow-up times²⁵. However, the heterogeneity of PRP preparation methods, injection protocols and patient characteristics remains a major limitation in all studies, making direct comparisons difficult^{26,27}. Also, recent evidence indicates that leukocyte-poor PRP may yield better results than leukocyte-rich preparations²⁸, underscoring the need for standardization.

The present study also investigated the measurement of the meniscus's T2 relaxation time. MRI T2

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mapping is a non-invasive quantitative technique that reflects the water content and collagen organization in articular soft tissues²⁹. T2 relaxation time was decreased in the anterior horn of the medial meniscus, but this was not statistically significant after Bonferroni correction for multiple comparisons. Therefore, the clinical significance of this finding is not known. Moreover, T2 changes are not a direct reflection of tissue repair, and no correlation analysis between imaging and clinical outcomes was performed.

During the follow-up period, no major adverse events such as infection were observed in the present study. PRP treatment was generally well tolerated, with mild, transient adverse events, including knee swelling, synovitis, and knee pain, which resolved after local ice application.

Some limitations should be taken into account. First, causal inference is limited by the retrospective design. Second, the absence of a control group limits the ability to distinguish the treatment effects from the natural course of the disease or a placebo response. Third, the relatively small sample size may have limited the ability to detect small effects. Although the sensitivity analysis indicated that the available sample size could detect approximately moderate or larger paired effects, smaller changes may not have been detected. Therefore, non-significant findings should not be interpreted as definitive evidence of no effect. Fourth, changes in physical activity levels and weight management over the follow-up period were not systematically documented. The study period did not include additional physical therapy interventions or NSAID treatment. These unmeasured lifestyle factors might have been confounders and their influence on the observed clinical outcomes cannot be fully ruled out. Finally, the PRP product was not directly analyzed in the laboratory, and the platelet concentration used was based on the manufacturer's specifications rather than measurements of the final preparation used for each patient. Thus, inter-individual differences in platelet and leukocyte concentrations could not be assessed. This limitation could have influenced clinical and imaging outcomes, reduced the reproducibility of the results, and limited the possibility of direct comparison with studies employing standardized PRP characterization protocols. Moreover, the PRP used was likely leukocyte-rich, as evidenced by the formation of a leukocyte layer during preparation. At the same time, leukocyte-poor PRP is currently more frequently recommended for intra-articular injections. This factor may be related to transient synovitis and should be considered when interpreting the study results.

In conclusion, PRP injections have shown improvements in pain, functional outcomes, and some quality of life parameters in patients with knee

osteoarthritis. Only in the unadjusted analysis by MRI T2 mapping changes were detected in the anterior horn of the medial meniscus. However, these results were not statistically significant after Bonferroni correction for multiple comparisons. Thus, no definitive conclusions can be drawn regarding the repair of meniscal tissue. These findings need to be confirmed in prospective randomized controlled trials with standardized PRP protocols.

Researcher Contribution Statement:

Idea and design: A.A.,B.K.,S.C.,G.G.; Data collection and processing: A.A.,B.K.,S.D.,S.C.,G.G.; Analysis and interpretation of data: G.O.,A.A.,B.K.; Writing of significant parts of the article: A.A.,S.D.,G.O.

Conflict of Interest Statement:

The authors of the article have no conflict of interest declarations.

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References

1. Hunter DJ, Lo GH. The management of osteoarthritis: an overview and call to appropriate conservative treatment. *Rheum Dis Clin North Am*. 2008;34:689-712.
2. Wallace IJ, Worthington S, Felson DT. Knee osteoarthritis has doubled in prevalence since the mid-20th century. *Proc Natl Acad Sci U S A*. 2017;114(35):9332-6.
3. Demiroğlu M, Söylemez S. Diz Osteoartritinde Trombositten Zengin Plazmanın Ağrı ve Fonksiyon Üzerinde Etkinliği. *Okmeydanı Tıp Dergisi*. 2017;33(4):206-12.
4. Campbell, K.A, Saltzman, BM, Mascarenhas, R, et al. Does intra-articular platelet-rich plasma injection provide clinically superior outcomes compared with other therapies in the treatment of knee osteoarthritis? A systematic review of overlapping meta-analyses. *Arthroscopy*. 2015;31(11):2213-21.
5. Kılınç SC, Güngörmüş M. Temporomandibular eklem osteoartritli hastalarda artrosentezi takiben yapılan trombositten zengin plazma, hyaluronik asit ve kortikosteroid enjeksiyonlarının temporomandibular eklem palpasyonunda oluşan ağrıya etkilerinin karşılaştırılması. *Atatürk Üniv. Dış Hek. Fak. Derg.* 2016;26(3):407-12.
6. Cole BJ, Karas V, Hussey K, et al. 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*. 2017;45(2):339-46.
7. O'Connell B, Wragg NM, Wilson SL. The use of PRP injections in the management of knee osteoarthritis. *Cell Tissue Res*. 2019;376(2):143-52.
8. Han SB, Seo IW, Shin YS. Intra-Articular Injections of Hyaluronic Acid or Steroids Associated With Better Outcomes Than Platelet-Rich Plasma, Adipose Mesenchymal Stromal Cells, or Placebo in Knee Osteoarthritis: A Network Meta-analysis. *Arthroscopy*. 2021;37(1):292-306.
9. Cerza F, Cami S, Carcangiu A, et al. Comparison between hyaluronic acid and platelet-rich plasma, intraarticular infiltration in the treatment of gonarthrosis. *Am J Sports Med*. 2012;40(12):2822-7.
10. Forogh B, Mianehsaz E, Shoaee S, et al. Effect of single injection of platelet-rich plasma in comparison with

- corticosteroid on knee osteoarthritis: a double-blind randomized clinical trial. *The Journal of Sports Medicine and Physical Fitness*. 2016;56(7-8):901-8.
11. Sánchez M, Anitua E, Azofra J, et al. Intra-articular injection of an autologous preparation rich in growth factors for the treatment of knee OA: a retrospective cohort study. *Clin Exp Rheumatol*. 2008;26:910-3.
 12. Shen L, Yuan T, Chen S, et al. The temporal effect of platelet-rich plasma on pain and physical function in the treatment of knee osteoarthritis: systematic review and meta-analysis of randomized controlled trials. *J Orthop Surg Res*. 2017;12(1):16.
 13. Dhillon MS, Patel S, Bansal T. Improvising PRP for use in osteoarthritis knee- upcoming trends and futuristic view. *J Clin Orthop Trauma*. 2019;10(1):32-5.
 14. Cook CS, Smith PA. Clinical Update: Why PRP Should Be Your First Choice for Injection Therapy in Treating Osteoarthritis of the Knee. *Curr Rev Musculoskelet Med*. 2018;11(4):583-92.
 15. Richards MM, Maxwell JS, Weng L, et al. Intra-articular treatment of knee osteoarthritis: from anti-inflammatories to products of regenerative medicine. *Phys Sportsmed*. 2016;44(2):101-8.
 16. Taniguchi Y, Yoshioka T, Kanamori A, et al. Intra-articular platelet-rich plasma (PRP) injections for treating knee pain associated with osteoarthritis of the knee in the Japanese population: a phase I and IIa clinical trial. *Nagoya J Med Sci*. 2018;80(1):39-51.
 17. Mosher TJ, Dardzinski BJ. Cartilage MRI T2 Relaxation Time Mapping: Overview and Applications. *Seminars in Musculoskeletal Radiology*. 2004;8(4):357-68.
 18. Chiarotto A, Maxwell LJ, Ostelo RW, Boers M, Tugwell P, Terwee CB. Measurement Properties of Visual Analogue Scale, Numeric Rating Scale, and Pain Severity Subscale of the Brief Pain Inventory in Patients With Low Back Pain: A Systematic Review *J Pain*. 2019;20(3):245-63. doi: 10.1016/j.jpain.2018.07.009. Epub 2018 Aug 10.
 19. Lins L, Carvalho FC. SF-36 total score as a single measure of health-related quality of life: Scoping review. *SAGE Open Med*. 2016;4:2050312116671725. doi: 10.1177/2050312116671725.
 20. Copsey B, Thompson JY, Vadher K, Ali U, Dutton SJ, Fitzpatrick R, Lamb SE, Cook JA. Problems persist in reporting of methods and results for the WOMAC measure in hip and knee osteoarthritis trials. *Qual Life Res*. 2019;28(2):335-43.
 21. Clegg A, Rogers L, Young J. Diagnostic test accuracy of simple instruments for identifying frailty in community-dwelling older people: a systematic review. *Age Ageing*. 2015;44(1):148-52. doi: 10.1093/ageing/afu157. Epub 2014 Oct 29.
 22. Ficek K, Kamiński T, Wach E, et al. Application of platelet rich plasma in sports medicine. *J Hum Kinet*. 2011;30:85-97.
 23. Chen X, Jones IA, Park C, et al. The efficacy of platelet-rich plasma on tendon and ligament healing: a systematic review and meta-analysis with bias assessment. *Am J Sports Med*. 2018;46:2020-32.
 24. Kabiri A, Esfandiari E, Esmaeili A, et al. Platelet-rich plasma application in chondrogenesis. *Adv Biomed Res*. 2014;3:138.
 25. Dai WL, Zhou AG, Zhang H, et al. Efficacy of Platelet-Rich Plasma in the Treatment of Knee Osteoarthritis: A Meta-analysis of Randomized Controlled Trials. *Arthroscopy*. 2017;33(3):659-70.
 26. Fadadu PP, Mazzola AJ, Hunter CW, et al. Review of concentration yields in commercially available platelet-rich plasma (PRP) systems: a call for PRP standardization. *Reg Anesth Pain Med*. 2019 Apr 16;rapm-2018-100356.
 27. Dhurat R, Sukesh M. Principles and Methods of Preparation of Platelet-Rich Plasma: A Review and Author's Perspective. *J Cutan Aesthet Surg*. 2014;7(4):189-97.
 28. Belk, JW, Kraeutler MJ, Houck DA et al. Platelet-Rich Plasma Versus Hyaluronic Acid for Knee Osteoarthritis A Systematic Review and Meta-analysis of Randomized Controlled Trials *The American Journal of Sports Medicine*. 2021;49(1):249-60. doi:10.1177/0363546520909397
 29. Baum T, Joseph GB, Karampinos DC, Jungmann PM, Link TM, Bauer JS. Cartilage and meniscal T2 relaxation time as non-invasive biomarker for knee osteoarthritis and cartilage repair procedures. *Osteoarthritis Cartilage*. 2013;21(10):1474-84. doi:10.1016/j.joca.2013.07.012. Epub 2013 Jul 27.