




Article

# Clinical and Functional Outcome of Meniscal Injuries Treated with Platelet-Rich Plasma: A Single-Center Case Series

Ivan Medina-Porqueres <sup>1,2,\*</sup> , Pablo Martin-Garcia <sup>3</sup>, Sofia Sanz-De-Diego <sup>4</sup>, Abel Gomez-Caceres <sup>2</sup>, Francisco Moya-Torrecilla <sup>5</sup>, Marcelo Reyes-Eldblom <sup>6</sup> and Daniel Rosado-Velazquez <sup>2</sup>

<sup>1</sup> Department of Physical Therapy, Faculty of Health Sciences, University of Malaga, 29071 Malaga, Spain

<sup>2</sup> Malaga Football Club, Medical Services, 29011 Malaga, Spain; gomezcaceresabel@gmail.com (A.G.-C.); dr\_rosado2002@hotmail.com (D.R.-V.)

<sup>3</sup> Onco-Hematology Unit, University Hospital Virgen de la Victoria, 29010 Malaga, Spain; martingarciapablo@hotmail.com

<sup>4</sup> Puerperium Unit, Regional Hospital of Malaga, 29011 Malaga, Spain; sofiasanzdediego@gmail.com

<sup>5</sup> Vithas Xanit International Hospital, 29630 Benalmadena, Spain; franmoya57@hotmail.com

<sup>6</sup> Costa del Sol Medical Center, 29620 Torremolinos, Spain; mreldblom@gmail.com

\* Correspondence: imp@uma.es



**Citation:** Medina-Porqueres, I.; Martin-Garcia, P.; Sanz-De-Diego, S.; Gomez-Caceres, A.; Moya-Torrecilla, F.; Reyes-Eldblom, M.; Rosado-Velazquez, D. Clinical and Functional Outcome of Meniscal Injuries Treated with Platelet-Rich Plasma: A Single-Center Case Series. *Int. J. Environ. Res. Public Health* **2022**, *19*, 7118. <https://doi.org/10.3390/ijerph19127118>

Academic Editors: Paul B. Tchounwou, Jagdish Khubchandani and Javier Abián-Vicén

Received: 11 March 2022

Accepted: 7 June 2022

Published: 10 June 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

**Abstract:** Meniscal injuries are among the most frequently encountered conditions in the knee joint. Therapeutic approaches are diverse and are largely dependent on the extent and location of the injury. The purpose of this study was to describe the clinical and functional outcomes of an intraarticular and percutaneous platelet-rich plasma (PRP) injection regime in patients with stable meniscal injuries. Demographics, the type of tear, affected knee, surgical procedure, type of intervention, follow-up period, and outcomes were recorded in all cases. Patient-reported outcome measures included the Knee Injury and Osteoarthritis Outcome Score (KOOS) and Tegner activity level scale. Overall patient satisfaction, quality of life, and pain intensity were also assessed. A total of 38 cases (8 females) had sustained a stable meniscal lesion (32 medial, 6 lateral) and met the inclusion criteria. All of them received three intraarticular and percutaneous PRP injections. Patients receiving the PRP injection regime reported clinically ( $p = 0.000$ ) and functionally ( $p = 0.000$  and  $p = 0.001$ ) significant improvement in all outcome measures during this interval. All patients reported they were very satisfied or satisfied with the outcome. The results of this study suggest that the treatment of stable meniscal injuries with percutaneous–intraarticular PRP injections can achieve a significant clinical and functional improvement.

**Keywords:** meniscus injury; growth factors; perimeniscal; knee

## 1. Introduction

Meniscal injuries are among the most frequently encountered and treated conditions in the knee joint and are responsible for clinical and functional impairment, with a relatively high annual cost [1]. Meniscus lesions are also common in young athletes, particularly in contact sports, with a mean annual incidence of approximately 60–70 per 100,000 [2]. When the integrity of the meniscus is altered, contact stresses within the knee joint are increased. Moreover, previous research has established a strong relationship between meniscal tear and cartilage deterioration [3,4].

Therefore, adequate treatment strategies are required to prevent these potential complications. Various therapeutic approaches have been described; these are largely dependent on the extent and location of the injury. The menisci have a unique vascular anatomy: only their peripheral third sustains a complete vascular supply [5]. Thus, the therapeutic results vary significantly depending on the specific tear pattern. Arthroscopic meniscal repair and meniscectomy have traditionally been the most commonly used treatment

methods [3]. However, different health authorities have recommended against the use of knee arthroscopy in patients aged  $\geq 40$  years with knee osteoarthritis (KOA) [6].

In recent years there has been growing interest in the preservation of meniscal integrity in both isolated and concomitant knee injuries. Accordingly, a more conservative approach for the treatment of meniscal injuries has been recommended in recent decades, especially in stable or degenerative meniscal injuries, as arthroscopic repair or meniscectomy may also increase the risk of KOA [4].

Platelet-rich plasma (PRP) is an autologous blood product obtained through the centrifugation of whole blood, therefore increasing the concentration of platelets that is believed to be 3 to 6 times higher than baseline values [7]. The physiological role of platelets in the natural healing process has led to the development of several research fields focusing on them as the main therapy for a variety of musculoskeletal conditions, particularly in certain cartilage pathologies [8,9]. There has been a growing interest in the application of PRP in the treatment of meniscal injuries in recent years; however, only a few studies have been reported [10–14]. Fibrochondrocyte migration and extracellular matrix production have been demonstrated to be positively affected by PRP cytokines in vitro [15,16]. Clinically, the use of PRP within the meniscal tear [11,17] and the surrounding tissues [18] has shown positive results. On the other hand, the results on the application of PRP during arthroscopic meniscal repairs have been inconclusive [13,14,19,20]. Nevertheless, the effect of a combined intraarticular and percutaneous PRP injection in stable meniscal injuries has not been studied previously. Accordingly, the purpose of this study was to determine the clinical and functional outcomes of patients with stable meniscal injuries treated with intraarticular and percutaneous PRP injections.

## 2. Materials and Methods

This study was retrospectively registered at ClinicalTrials.gov (NCT04040283). The study was performed in accordance with the Declaration of Helsinki as well as the International Conference on Harmonization: Guidelines for Good Clinical Practice. The study was approved by our Institutional Review Board (n. 1-2020-H). All patients gave their consent to allow their clinical and radiological data to be used for research purposes.

### 2.1. Patient Selection

Data were withdrawn from our electronic medical record system. We retrospectively identified all patients attending our institution with a diagnosis of meniscal lesion confirmed by magnetic resonance imaging (MRI) and who were treated with a PRP injection between May 2015 and December 2019. Patients with meniscus injuries who had failed conservative treatment after a minimum period of 6 weeks were included. The following conservative therapies before PRP therapy were accepted: stretching, orthosis, physiotherapy, therapeutic exercise, oral analgesia, electrothermal therapy, and extracorporeal shock wave therapy. These conservative therapies were not monitored by our researchers since all patients were subjected to this conservative approach before consulting our institution.

The following information was collected: demographic data, past medical history, diagnostic imaging, meniscus injury pattern, previous surgical interventions, and details about subsequent revisions. Meniscus injuries were classified according to Reicher et al., who defined four grades on MRI: Grade I (*no tear*) are defined as homogeneously black meniscus; Grade II (*unlikely tear*), with a region of minimally increased signal intensity within the meniscus, usually not present on two adjacent scans; Grade III (*probable tear*), with a small, linear region of increased signal intensity/a small-to-moderate nonlinear area of increased signal intensity within the meniscus; Grade IV (*definite tear*), with gross distortion of the normal shape, truncation of the meniscus/a large focus or line of increased signal intensity within the meniscus [1]. For the purpose of this retrospective analysis, Grades I–III were considered as stable injuries since neither gross distortion nor truncation of the meniscal material existed in these conditions. Patients subjected to previous steroid/hyaluronic intraarticular injections, a history of complex/unstable meniscal

tears [21]—displaced meniscal fragment, presence of fluid signal intensity within the tear on T2-weighted images, tear > 10 mm in length, and tears with complex patterns—, treated with nonsteroidal antiinflammatory drugs (NSAIDs) within 2 days of the PRP injection, with local infections at the site of the procedure, or who underwent knee surgery were excluded. In addition, individuals suffering from severe diabetes or hyperuricemia, bleeding disorders, severe cardiovascular disease, or those who were receiving anticoagulant treatment were also discarded. Pregnant women and individuals treated with systemic corticosteroid or subjected to a previous corticosteroid injection at the affected site within 1 month of the PRP injection were also excluded.

## 2.2. Platelet-Rich Plasma Injection

A total of 45 mL whole blood was collected from the medial cubital vein of every patient. Then, the blood underwent a standardized protocol of preparation, which consisted of one centrifugation (Auxilab, Nahita Blue, FugelabGB10, Navarra, Spain) at 1800 rpm for 8 min. Each patient received the same 6 mL intraarticular injection into the affected knee. The injection site on the skin was prepped under aseptic conditions with povidone-iodine solution. Patients were placed in a supine position with knee flexion of 90 degrees, and a lateral approach to the knee was used. PRP was injected intraarticularly using a 22-gauge needle with classic infrapatellar approach [22,23]. Percutaneous PRP application was performed based on previous described approaches [18,24]. A 25-gauge needle was advanced until the meniscus wall was reached. Once the needle touched this wall it was retracted by 1 mm and an injection of 0.5 mL of PRP around perimeniscal tissues was performed, using the abovementioned strict aseptic administration technique. This procedure was repeated 2–3 times into the adjacent perimeniscal aspect, with a total 1.5–2 mL of PRP injected. Then, the patients were asked to mobilize the knee to facilitate the dissemination of the PRP. A total of 3 injections were administered on seven-day intervals during a three-week period. The injection point was determined by the identification of anatomical landmarks. The tibial plateau and femoral notch were used as references to localize the joint line. Meniscal tissue was identified by increase and loss of resistance across the joint line, which corresponds to meniscus “red zone” [25]. No local anesthetic was administered before injection to prevent a possible negative interaction due to its potential negative influence on PRP effectiveness through pH modifications [26]. All the practitioners who performed PRP injection treatment in our institution followed the same protocol regarding preparation and maintenance of aseptic technique. Patients were instructed to avoid the use of NSAIDs during treatment up to 2 weeks after the last injection, to prevent possible negative interactions with the PRP. Paracetamol was recommended as an analgesic treatment when needed. Participants were advised to apply ice routinely and were allowed to fully weight bear and to resume their daily living activities. However, patients were advised to avoid impact activities such as running and jumping up to 2 weeks after the last PRP injection. A gradual increase in weightbearing/impact activities was recommended over the following 4–8 weeks. Return to sport was allowed on the individual’s tolerance and requirements.

## 2.3. Clinical and Functional Evaluation

The clinical and functional evaluation were considered the primary outcomes of this study. Clinical improvement was measured by Numeric Pain Rating Scale (NPRS) and the Feeling Thermometer Scale. Functional capacities were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS) and Tegner activity scale. Patients’ satisfaction with PRP therapy was used as a secondary outcome. Furthermore, patients were asked if they would receive the PRP procedure again in the same clinical situation. The NPRS indicates the subjective feeling of pain, with 0 indicating no pain and 100 indicating the worst pain the patient has ever experience [27]. The KOOS is a reliable, validated, and reproducible patient-reported outcome employed to evaluate the symptoms and function of patients with knee ailments [28,29]. This 42-item self-report questionnaire is comprised by

five different subscales, “Symptoms”, “Pain”, “Activities of Daily Living” (ADL), “Sport”, and “Quality Of Life” (QoL). The result is a percentage score that ranges from 0 to 100 (0 = extreme knee problems, 100 = no knee problem) [30]. Differences of 8 points and over have been considered to be clinically relevant [31]. The Feeling Thermometer is a visual analog scale from 0 to 100 that has previously been employed as a valid measure of health status in clinical research due to its ease of administration and simplicity [32]. The Tegner activity scale is a one-item score based on daily activities, recreation, and competitive sports. The patients select the level of participation that best describes their current level of activity. A score of 0 implies “sick leave or disability pension because of knee problems”, whereas a score of 10 corresponds to participation in national and international elite competitive sports. Those participating in recreational or competitive sport will select activity levels between 6 and 10 [33]. Patients’ overall satisfaction with PRP therapy was evaluated by asking the patients if they were very satisfied, satisfied, partially satisfied, or unsatisfied. Additionally, a 10-point NPRS for pain was used [34].

#### 2.4. Statistical Analysis

Statistical analysis was performed using SPSS statistics, version 25 (IBM SPSS, Armonk, NY, USA) to compare clinical and functional outcomes between pre-intervention and post-intervention groups. Continuous variables were presented as means with their corresponding standard deviations (SD). The distribution of continuous variables was analyzed using the Shapiro–Wilk test. Treatment safety and efficacy were assessed by comparing the pre- and post-treatment scores using paired-samples *t*-test. A *p*-value < 0.05 was considered statistically significant for all comparisons.

### 3. Results

During the study period, we identified a total of 38 patients with stable meniscal injuries (i.e., 32 medial and 6 lateral meniscal injuries) who met our inclusion criteria. The mean patient age at PRP intervention was  $50.68 \pm 9.65$  years (range, 29–72 years) and the mean body mass index (BMI) was  $25.77 \pm 3.37$  kg/m<sup>2</sup> (range, 17.63–33.64 kg/m<sup>2</sup>). The mean follow-up period after PRP therapy was  $75.92 \pm 31.7$  days (range, 39–190 days). The left knee was affected in 13 patients (31.6%). We observed that the most common meniscal tear type was Grade III injury ( $n = 31$ ; 81.57%). No bilateral injuries were identified in our series. The demographic features of the study group are presented in Table 1. More than half of the 38 evaluated patients ( $n = 31$ ; 81.57%) regularly practiced recreational sports (i.e., eight gym, five soccer, four tennis/paddle, three cross-fit, and three yoga) at an amateur level. In terms of physical workload, no heavy physical workload (i.e., manual laborers or construction workers) was reported. However, a small group of patients ( $n = 3$ , 7.89%) had occupations requiring an average workload (i.e., electricians or plumbers).

**Table 1. Patient demographics.** Values presented as mean  $\pm$  standard deviation.

Variable	Value
Patients eligible for the study, No.	38
Gender (female/male), No.	8/30
Age at the time of intervention, mean, y	$50.68 \pm 9.65$
Height, cm	$1.75 \pm 0.66$
Weight, kg	$79.44 \pm 13.25$
Body mass index	$25.77 \pm 3.37$
Affected knee (right/left), No.	25/12
Affected meniscus (medial/lateral), No.	32/6
Meniscus injury grade, No. (%)	
Grade I	1 (2.6)
Grade II	6 (15.8)
Grade III	31 (81.6)

Table 2 gathers in detail the clinical and functional outcomes of each patient along with the subjective overall satisfaction. The average baseline and post-treatment NPRS scores were  $5.86 \pm 1.91$  and  $1.59 \pm 1.36$  ( $p = 0.00$ ), respectively, whereas the mean baseline and post-treatment Feeling Thermometer values were  $67.89 \pm 16.42$  and  $86.31 \pm 6.74$  ( $p = 0.00$ ), respectively.

**Table 2. Clinicofunctional relevant data of patients undergoing platelet-rich plasma injections.**  
B, body; PH, posterior horn; A, anterior horn.

Case NO.	Age (YR)	Meniscal Location (Knee, Meniscus; Grade, Tear Location)	Duration of Symptoms, Days	Koos Score Pre-Intervention	Follow-Up, Days	Level of Satisfaction	Koos Score Post-Intervention
1	49	Right Medial; Grade III, PH	30	63	56	Very satisfied	83
2	47	Left Medial; Grade III, PH	45	50	56	Satisfied	83
3	48	Right Medial; Grade II, PH	150	80	56	Satisfied	89
4	53	Right Medial; Grade III, PH	90	81	56	Satisfied	86
5	52	Left Medial; Grade III, PH	100	60	56	Very satisfied	81
6	48	Right Medial; Grade III, PH	365	80	56	Satisfied	89
7	48	Right Medial; Grade III, PH	25	88	56	Very satisfied	91
8	46	Right Medial; Grade III, B + PH	190	35	190	Very satisfied	96
9	40	Right Medial; Grade III, B + PH	93	54	93	Very satisfied	89
10	69	Right Medial; Grade II, PH	78	40	78	Very satisfied	90
11	51	Left Medial; Grade III, B + PH	73	57	73	Very satisfied	100
12	61	Right Medial; Grade III, B + PH	57	45	57	Very satisfied	80
13	42	Left Medial; Grade II, PH	59	63	59	Very satisfied	86
14	51	Right Medial; Grade III, B + PH	89	23	89	Satisfied	88
15	66	Right Medial; Grade III, PH	71	29	71	Satisfied	62
16	52	Left Medial; Grade III, PH	129	76	129	Very satisfied	98
17	60	Right Medial; Grade III, PH	142	44	142	Very satisfied	92
18	38	Right Medial; Grade III, PH	43	23	43	Satisfied	95
19	42	Right Medial; Grade III, PH	69	33	69	Very satisfied	96
20	55	Left Medial; Grade III, PH	56	15	56	Satisfied	30
21	52	Both Lateral; Grade III, B + PH	104	17	104	Very satisfied	96
22	67	Left Lateral; Grade III, PH	61	13	61	Satisfied	92
23	56	Left Medial; Grade III, PH	96	17	96	Very satisfied	95
24	32	Left Medial; Grade II, PH	39	13	39	Very satisfied	96
25	47	Right Medial; Grade III, PH	87	66	87	Very satisfied	79
26	39	Right Medial; Grade III, PH	73	63	73	Satisfied	83
27	49	Right Medial; Grade III, PH	74	18	74	Satisfied	93
28	72	Left Medial; Grade II, B + PH	96	27	96	Very satisfied	74

Table 2. Cont.

Case NO.	Age (YR)	Meniscal Location (Knee, Meniscus; Grade, Tear Location)	Duration of Symptoms, Days	Koos Score Pre-Intervention	Follow-Up, Days	Level of Satisfaction	Koos Score Post-Intervention
29	48	Right Both; Grade III, PH (medial), B (lateral)	46	23	46	Very satisfied	83
30	57	Right Medial; Grade III, PH	89	24	89	Very satisfied	50
31	57	Right Medial, Grade I, PH	45	27	45	Very satisfied	93
32	49	Right Lateral; Grade II, PH	67	22	67	Very satisfied	95
33	51	Right Lateral; Grade III, PH	56	63	56	Satisfied	93
34	49	Right Medial; Grade III, PH	134	11	134	Very satisfied	90
35	40	Right Lateral; Grade III, AH	43	62	43	Satisfied	80
36	48	Left Medial; Grade III, B + PH	92	24	92	Very satisfied	97
37	29	Left Medial; Grade III, PH	93	29	93	Very satisfied	87
38	66	Right Medial, Grade III, PH	49	34	49	Very satisfied	86

The participants experienced a significant improvement in the total KOOS score (i.e.,  $41.89 \pm 22.89$  baseline and  $85.94 \pm 13.5$  post-treatment, ( $p = 0.000$ )). The post-treatment KOOS subscores also showed good to excellent results: KOOS symptoms  $86.36 \pm 10.19$ , KOOS pain  $89 \pm 12.74$ , KOOS ADL  $90.97 \pm 11.89$ , KOOS 5 Sport/Rec  $78.97 \pm 22.16$ , and KOOS QOL  $78.72 \pm 12.1$ . The mean Tegner scale also showed as significantly improved (i.e.,  $3.73 \pm 1.67$  baseline and  $4.73 \pm 1.70$  post-treatment, ( $p = 0.001$ )), indicating a moderate level of sports participation (Table 3). All patients were either very satisfied or satisfied with the outcome. None of the patients stated that they would not undergo the same procedure again, or needed additional surgical interventions. No treatment-related adverse effects were reported.

**Table 3. Comparison of patients' outcomes pre- and post-intervention.** Numerical Pain Rating Index Scale (NPRS); Knee Injury Osteoarthritis Outcome Score (KOOS); standard deviation (SD); standard Error (SE).

Outcome	Pre-Intervention		Post-Intervention		p-Value
	Mean	SD/SE	Mean	SD/SE	
NPRS	5.86	1.91/0.31	1.5789	1.34/1.34	0.000
Tegner	3.73	1.67/0.27	4.7368	1.70/0.27	0.001
KOOS	41.89	22.96/3.72	85.94	13.50/2.19	0.000
Feeling thermometer	67.89	16.42/2.66	86.31	6.74/1.09	0.000

#### 4. Discussion

This investigation presents the results referring to the largest series of PRP-treated meniscal injuries sustained by a non-professional athletic population. In the present retrospective study, a positive effect for three PRP intraarticular and percutaneous injections (once a week) was found, with pain reduction, health status amelioration, and function improvement at a mean follow-up of 75.92 days. Our findings seem to confirm the clinical/functional benefit of PRP percutaneous injections for meniscal lesions, as previously described by Blanke et al. for intrasubstance meniscus injury [18].

The most important finding in this present study was that the subjective scores of the KOOS, Tegner, Feeling Thermometer, and NPRS after PRP therapy achieved significant improvements with a patients' satisfaction rate of 100% (very satisfied/satisfied) at

a mean follow-up of 75.92 days. No complications or adverse effects were recorded in our series, highlighting PRP as a reliable and safe alternative to treat stable meniscal lesions and/or to postpone invasive surgical procedures. Thus, these data may add preliminary promising results to the existing knowledge. Accordingly, combined percutaneous and intraarticular PRP injections have a positive influence on clinical and functional outcomes in the context of a meniscal injury. The rationale for this could be explained by the action of different growth factors. Fibroblast growth, platelet-derived, and transforming growth factor-beta (TGF- $\beta$ 1) factors may play a role in the scar formation process, especially at the red-red zone [10,35]. Moreover, in vitro studies have reported that meniscal cells in the white/white zone may favorably respond to exposure to PDGF-AB [36]. A similar isolated perimeniscal approach has been proposed in the past for treating a cohort of patients with medial meniscus protrusion associated with medial collateral ligament displacement in people with knee OA. In this series corticosteroid ultrasound-guided injections were applied with promising clinical results [24].

Meniscal injuries are common and disabling knee conditions, which are commonly advocated for surgical procedures. They also represent an important economic burden due to their high prevalence in the general population [37,38]. Research on conservative approaches for the treatment of meniscal injuries is scarce. Nonoperative choices include rest, immobilization, weightbearing limitation, physical therapy, therapeutic exercise, and intraarticular injections, steroid or hyaluronic acid. No drugs or therapies have proven to result in clinically relevant benefits at 12-months of follow-up in comparison with arthroscopic partial meniscectomy [39]. Recent research has proven the musculoskeletal benefits of PRP on various conditions in sports medicine and orthopedics fields [40–42]. Most of the published evidence on PRP has focused on its influence to treat tendon, muscle, and cartilage disorders. However, few attempts have been made regarding the use of PRP for the treatment of meniscal injuries, most of them being isolated case reports [17,18] and short series [11,43–45]. Some other attempts have investigated the additive effect of PRP over a previous surgical procedure [13,14,20]. Additionally, animal studies have demonstrated a beneficial effect on the controverted white/white zone when treated with PRP [46]. The additive effect of PRP has been evaluated on open meniscal repair for grade 2–3 horizontal meniscal injuries through a case–control study. PRP improved clinical outcomes when injected into the lesion at the end of the procedure after a standard open meniscal repair, and when compared with this surgical procedure alone [14]. On the other hand, a preclinical study that analyzed the effects of PRP in meniscal tissue regeneration employing a gelatin hydrogel described remarkable healing properties. This investigation focused on the inner avascular part of meniscal injury in vitro and in vivo [10]. However, the independent effect of PRP over injured menisci was not assessed.

A novel aspect in our series was the combination of both intraarticular and percutaneous PRP injections. This combined approach may have multiplied the described potential influence of the PRP product on the fibrocartilage tissue. Others have suggested that this early success of PRP injections may have been related to the reduction in synovial inflammation and the creation of a more balanced intraarticular balance rather than the healing of the meniscus itself [47]. In any case, our findings represent a potential area of research as no previous reports have been published in the scientific literature. Accordingly, this approach could enhance meniscal healing through a more localized action of the PRP. Patients were advised to perform stretching exercises after PRP injections. In addition, a strengthening regime with progressive weightbearing activities was recommended. This regime was based on patients' tolerance, which was defined as no swelling or pain immediately following or during activities, as well as the day after.

The standardization of PRP parameters is still not possible with the current techniques and knowledge due to a subject's own variability in terms of circulating blood products. Different methodologies have been proposed regarding PRP preparation as PRP research have been debating this extreme since its introduction [48,49]. The number of employed platelets or presence of white and red cells may all represent significant outcome param-

ters. However, our study did not calculate platelet or white/red cell concentrations, which may constitute a significant limitation, so dose–response correlation could not then be established. In any event, analysis of the composition of the injected PRP is only reported in one out of three studies [46]. In parallel, a single centrifugation involving a 2–3 fold increase in platelet concentration from baseline values has been described from PRP therapy origins [50]. Two-stage techniques have also been proposed with acceptable platelet concentrations [42]. Nevertheless, a second spin may decrease platelet viability due to a lytic effect [51]. As with previously published PRP clinical studies, our series involved a single-spin centrifugation protocol.

Surgical management often includes structural modification of the meniscal tissue with obvious implications for the biomechanics of the knee. The resection of these structures increases contact stress on cartilage and accelerates the development of knee compartment osteoarthritis [52]. In addition, meniscectomies might lead to post-surgical complications, as with any given procedure. Potential infections, systemic adverse reactions, cartilage damage, or excessive meniscal resection may occur. Moreover, intra-meniscal lesions cannot be detected arthroscopically in all cases since these injuries do not extend to the articular surface. In this study, clinical and functional improvements were achieved with no significant complications using minimally invasive procedure. For these reasons, we consider that surgical interventions for stable meniscal lesions should be reserved for cases where PRP injections are not effective.

There are some limitations in this study that must be addressed [53]. Firstly, due to the retrospective, observational nature of this study, a causal relationship between the intervention and outcomes could not be established. Secondly, our eligibility criteria were not randomized as we formulated a representative group of patients from our clinical practice, this inherently implies a possible selection bias. Finally, the study population was relatively small, which limits the overall validity of our results. In addition, no imaging follow-up was included in our cohort, and comparisons between the meniscal structure before and after treatment, as in previous reports [11,18,20], were not performed. However, evidence in the literature suggests that asymptomatic knees may hold structurally damaged menisci; however, this clinical scenario is more common in a degenerative setting [54,55]. In our series, the role of PRP in promoting meniscal defect healing was not confirmed as no radiological follow-up was achieved. One may also highlight the absence of imaging guidance for our PRP injections. Previous research has shown no advantages of ultrasound guided infiltrations over direct palpation of the most tender or affected area as guidance for the injection of joint and soft tissue injuries [56–59].

## 5. Conclusions

This retrospective, single-center case series showed that PRP is a safe and effective treatment modality for stable meniscal injuries through percutaneous and intraarticular PRP injections, and it achieved clinically relevant and statistically significant improvements in patient-reported pain and functional outcomes. These encouraging findings should pave the way toward future controlled, randomized, prospective clinical trials on larger patient populations in order to formally determine whether PRP injections could be an alternative to surgical treatment for stable meniscal injuries.

**Author Contributions:** Conceptualization, I.M.-P.; methodology, I.M.-P. and D.R.-V.; validation, A.G.-C., M.R.-E. and F.M.-T.; formal analysis, I.M.-P.; investigation, I.M.-P., P.M.-G. and S.S.-D.-D.; resources, I.M.-P., P.M.-G., S.S.-D.-D., M.R.-E. and F.M.-T.; data curation, I.M.-P. and D.R.-V.; writing—original draft preparation, I.M.-P.; writing—review and editing, D.R.-V. and A.G.-C.; supervision, M.R.-E. and F.M.-T. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Malaga Football Club (protocol code 12020-H and November 2020) for studies involving humans.



**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Acknowledgments:** We acknowledge Raquel Navarro-Ger for her contributions and participation during the data collection and interventions.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

## References

1. Mather, R.C.; Garrett, W.E.; Cole, B.J.; Hussey, K.; Bolognesi, M.P.; Lassiter, T.; Orlando, L.A. Cost-Effectiveness Analysis of the Diagnosis of Meniscus Tears. *Am. J. Sports Med.* **2015**, *43*, 128–137. [[CrossRef](#)] [[PubMed](#)]
2. Hede, A.; Jensen, D.B.; Blyme, P.; Sonne-Holm, S. Epidemiology of Meniscal Lesions in the Knee. 1215 Open Operations in Copenhagen 1982–1984. *Acta Orthop. Scand.* **1990**, *61*, 435–437. [[CrossRef](#)]
3. Roos, H.; Laurén, M.; Adalberth, T.; Roos, E.M.; Jonsson, K.; Lohmander, L.S. Knee Osteoarthritis after Meniscectomy: Prevalence of Radiographic Changes after Twenty-One Years, Compared with Matched Controls. *Arthritis Rheum.* **1998**, *41*, 687–693. [[CrossRef](#)]
4. McDermott, I. Meniscal Tears, Repairs and Replacement: Their Relevance to Osteoarthritis of the Knee. *Br. J. Sports Med.* **2011**, *45*, 292–297. [[CrossRef](#)]
5. Gray, J.C. Neural and Vascular Anatomy of the Menisci of the Human Knee. *J. Orthop. Sports Phys. Ther.* **1999**, *29*, 23–30. [[CrossRef](#)] [[PubMed](#)]
6. Kiadaliri, A.; Bergkvist, D.; Dahlberg, L.E.; Englund, M. Impact of a National Guideline on Use of Knee Arthroscopy: An Interrupted Time-Series Analysis. *Int. J. Qual. Health Care J. Int. Soc. Qual. Health Care* **2019**, *31*, G113–G118. [[CrossRef](#)]
7. Fitzpatrick, J.; Bulsara, M.K.; McCrory, P.R.; Richardson, M.D.; Zheng, M.H. Analysis of Platelet-Rich Plasma Extraction. *Orthop. J. Sports Med.* **2017**, *5*, 2325967116675272. [[CrossRef](#)]
8. Xie, X.; Zhang, C.; Tuan, R.S. Biology of Platelet-Rich Plasma and Its Clinical Application in Cartilage Repair. *Arthritis Res. Ther.* **2014**, *16*, 204. [[CrossRef](#)]
9. Sundman, E.A.; Cole, B.J.; Karas, V.; Della Valle, C.; Tetreault, M.W.; Mohammed, H.O.; Fortier, L.A. The Anti-Inflammatory and Matrix Restorative Mechanisms of Platelet-Rich Plasma in Osteoarthritis. *Am. J. Sports Med.* **2014**, *42*, 35–41. [[CrossRef](#)] [[PubMed](#)]
10. Ishida, K.; Kuroda, R.; Miwa, M.; Tabata, Y.; Hokugo, A.; Kawamoto, T.; Sasaki, K.; Doita, M.; Kurosaka, M. The Regenerative Effects of Platelet-Rich Plasma on Meniscal Cells in Vitro and Its in Vivo Application with Biodegradable Gelatin Hydrogel. *Tissue Eng.* **2007**, *13*, 1103–1112. [[CrossRef](#)]
11. Özyalvaç, O.N.; Tüzüner, T.; Gürpınar, T.; Obut, A.; Acar, B.; Akman, Y.E. Radiological and Functional Outcomes of Ultrasound-Guided PRP Injections in Intrasubstance Meniscal Degenerations. *J. Orthop. Surg. Hong Kong* **2019**, *27*, 2309499019852779. [[CrossRef](#)]
12. Hutchinson, I.D.; Rodeo, S.A.; Perrone, G.S.; Murray, M.M. Can Platelet-Rich Plasma Enhance Anterior Cruciate Ligament and Meniscal Repair? *J. Knee Surg.* **2015**, *28*, 19–28. [[CrossRef](#)]
13. Griffin, J.W.; Hadeed, M.M.; Werner, B.C.; Diduch, D.R.; Carson, E.W.; Miller, M.D. Platelet-Rich Plasma in Meniscal Repair: Does Augmentation Improve Surgical Outcomes? *Clin. Orthop.* **2015**, *473*, 1665–1672. [[CrossRef](#)]
14. Pujol, N.; Salle De Chou, E.; Boisrenoult, P.; Beaufils, P. Platelet-Rich Plasma for Open Meniscal Repair in Young Patients: Any Benefit? *Knee Surg. Sports Traumatol. Arthrosc.* **2015**, *23*, 51–58. [[CrossRef](#)]
15. Bhargava, M.M.; Attia, E.T.; Murrell, G.A.; Dolan, M.M.; Warren, R.F.; Hannafin, J.A. The Effect of Cytokines on the Proliferation and Migration of Bovine Meniscal Cells. *Am. J. Sports Med.* **1999**, *27*, 636–643. [[CrossRef](#)]
16. McNulty, A.L.; Guilak, F. Integrative Repair of the Meniscus: Lessons from in Vitro Studies. *Biorheology* **2008**, *45*, 487–500. [[CrossRef](#)]
17. Guenoun, D.; Magalon, J.; de Torquemada, I.; Vandeville, C.; Sabatier, F.; Champsaur, P.; Jacquet, C.; Ollivier, M. Treatment of Degenerative Meniscal Tear with Intrameniscal Injection of Platelets Rich Plasma. *Diagn. Interv. Imaging* **2020**, *101*, 169–176. [[CrossRef](#)]
18. Blanke, F.; Vavken, P.; Haenle, M.; von Wehren, L.; Pagenstert, G.; Majewski, M. Percutaneous Injections of Platelet Rich Plasma for Treatment of Intrasubstance Meniscal Lesions. *Muscles Ligaments Tendons J.* **2015**, *5*, 162–166. [[CrossRef](#)]
19. Dai, W.-L.; Zhang, H.; Lin, Z.-M.; Shi, Z.-J.; Wang, J. Efficacy of Platelet-Rich Plasma in Arthroscopic Repair for Discoid Lateral Meniscus Tears. *BMC Musculoskelet. Disord.* **2019**, *20*, 113. [[CrossRef](#)]
20. Kaminski, R.; Kulinski, K.; Kozar-Kaminska, K.; Wielgus, M.; Langner, M.; Wasko, M.K.; Kowalczewski, J.; Pomianowski, S. A Prospective, Randomized, Double-Blind, Parallel-Group, Placebo-Controlled Study Evaluating Meniscal Healing, Clinical Outcomes, and Safety in Patients Undergoing Meniscal Repair of Unstable, Complete Vertical Meniscal Tears (Bucket Handle) Augmented with Platelet-Rich Plasma. *BioMed Res. Int.* **2018**, *2018*, 9315815. [[CrossRef](#)]

21. Vande Berg, B.C.; Poilvache, P.; Duchateau, F.; Lecouvet, F.E.; Dubuc, J.E.; Maldague, B.; Malghem, J. Lesions of the Menisci of the Knee: Value of MR Imaging Criteria for Recognition of Unstable Lesions. *AJR Am. J. Roentgenol.* **2001**, *176*, 771–776. [[CrossRef](#)]
22. Esenyel, C.; Demirhan, M.; Esenyel, M.; Sonmez, M.; Kahraman, S.; Senel, B.; Ozdes, T. Comparison of Four Different Intra-Articular Injection Sites in the Knee: A Cadaver Study. *Knee Surg. Sports Traumatol. Arthrosc.* **2007**, *15*, 573–577. [[CrossRef](#)]
23. Chavez-Chiang, C.E.; Sibbitt, W.L.; Band, P.A.; Chavez-Chiang, N.R.; DeLea, S.L.; Bankhurst, A.D. The Highly Accurate Anteriolateral Portal for Injecting the Knee. *Sports Med. Arthrosc. Rehabil. Ther. Technol. SMARTT* **2011**, *3*, 6. [[CrossRef](#)]
24. Di Sante, L.; Venditto, T.; Ioppolo, F.; Paoloni, M.; Mangone, M.; Alviti, F. Ultrasound Guided Injection of a Painful Knee Osteoarthritis with Medial Meniscus Extrusion: A Case Series Study. *Muscles Ligaments Tendons J.* **2017**, *7*, 331–337. [[CrossRef](#)]
25. Chivers, M.D.; Howitt, S.D. Anatomy and Physical Examination of the Knee Menisci: A Narrative Review of the Orthopedic Literature. *J. Can. Chiropr. Assoc.* **2009**, *53*, 319–333.
26. Foster, T.E.; Puskas, B.L.; Mandelbaum, B.R.; Gerhardt, M.B.; Rodeo, S.A. Platelet-Rich Plasma: From Basic Science to Clinical Applications. *Am. J. Sports Med.* **2009**, *37*, 2259–2272. [[CrossRef](#)]
27. McCaffery, M.; Pasero, C. Teaching Patients to Use a Numerical Pain-Rating Scale. *Am. J. Nurs.* **1999**, *99*, 22. [[CrossRef](#)]
28. Hajewski, C.J.; Baron, J.E.; Glass, N.A.; Duchman, K.R.; Bollier, M.; Wolf, B.R.; Westermann, R.W. Performance of the Patient-Reported Outcome Measurement Information System in Patients with Patellofemoral Instability. *Orthop. J. Sports Med.* **2020**, *8*, 1302–1311. [[CrossRef](#)]
29. Roos, E.M.; Toksvig-Larsen, S. Knee Injury and Osteoarthritis Outcome Score (KOOS)—Validation and Comparison to the WOMAC in Total Knee Replacement. *Health Qual. Life Outcomes* **2003**, *1*, 17. [[CrossRef](#)]
30. Tanner, S.M.; Dainty, K.N.; Marx, R.G.; Kirkley, A. Knee-Specific Quality-of-Life Instruments: Which Ones Measure Symptoms and Disabilities Most Important to Patients? *Am. J. Sports Med.* **2007**, *35*, 1450–1458. [[CrossRef](#)]
31. Roos, E.M.; Roos, H.P.; Lohmander, L.S.; Ekdahl, C.; Beynnon, B.D. Knee Injury and Osteoarthritis Outcome Score (KOOS)—Development of a Self-Administered Outcome Measure. *J. Orthop. Sports Phys. Ther.* **1998**, *28*, 88–96. [[CrossRef](#)]
32. Räsänen, P.; Roine, E.; Sintonen, H.; Semberg-Konttinen, V.; Rynänen, O.-P.; Roine, R. Use of Quality-Adjusted Life Years for the Estimation of Effectiveness of Health Care: A Systematic Literature Review. *Int. J. Technol. Assess. Health Care* **2006**, *22*, 235–241. [[CrossRef](#)]
33. Tegner, Y.; Lysholm, J. Rating Systems in the Evaluation of Knee Ligament Injuries. *Clin. Orthop.* **1985**, *198*, 43–49. [[CrossRef](#)]
34. Jensen, M.P.; Karoly, P.; Braver, S. The Measurement of Clinical Pain Intensity: A Comparison of Six Methods. *Pain* **1986**, *27*, 117–126. [[CrossRef](#)]
35. Deponi, D.; Di Giancamillo, A.; Scotti, C.; Peretti, G.M.; Martin, I. Animal Models for Meniscus Repair and Regeneration. *J. Tissue Eng. Regen. Med.* **2015**, *9*, 512–527. [[CrossRef](#)]
36. Tumia, N.S.; Johnstone, A.J. Platelet Derived Growth Factor-AB Enhances Knee Meniscal Cell Activity in Vitro. *Knee* **2009**, *16*, 73–76. [[CrossRef](#)]
37. Momaya, A. Editorial Commentary: Save the Meniscus? Show Me the Money! *Arthrosc. J. Arthrosc. Relat. Surg.* **2019**, *35*, 3287–3288. [[CrossRef](#)]
38. Rogers, M.; Dart, S.; Odum, S.; Fleischli, J. A Cost-Effectiveness Analysis of Isolated Meniscal Repair Versus Partial Meniscectomy for Red-Red Zone, Vertical Meniscal Tears in the Young Adult. *Arthrosc. J. Arthrosc. Relat. Surg.* **2019**, *35*, 3280–3286. [[CrossRef](#)]
39. van de Graaf, V.A.; Wolterbeek, N.; Mutsaerts, E.L.A.R.; Scholtes, V.A.B.; Saris, D.B.F.; de Gast, A.; Poolman, R.W. Arthroscopic Partial Meniscectomy or Conservative Treatment for Nonobstructive Meniscal Tears: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Arthrosc. J. Arthrosc. Relat. Surg.* **2016**, *32*, 1855–1865.e4. [[CrossRef](#)]
40. Ficek, K.; Kamiński, T.; Wach, E.; Cholewiński, J.; Ciężczyk, P. Application of Platelet Rich Plasma in Sports Medicine. *J. Hum. Kinet.* **2011**, *30*, 85–97. [[CrossRef](#)]
41. Andia, I.; Abate, M. Platelet-Rich Plasma: Combinational Treatment Modalities for Musculoskeletal Conditions. *Front. Med.* **2018**, *12*, 139–152. [[CrossRef](#)] [[PubMed](#)]
42. Mehrabani, D.; Seghatchian, J.; Acker, J.P. Platelet Rich Plasma in Treatment of Musculoskeletal Pathologies. *Transfus. Apher. Sci.* **2019**, *58*, 102675. [[CrossRef](#)] [[PubMed](#)]
43. Urzen, J.M.; Fullerton, B.D. Nonsurgical Resolution of a Bucket Handle Meniscal Tear: A Case Report. *PM R* **2016**, *8*, 1115–1118. [[CrossRef](#)]
44. Razaq, S.; Ejaz, A.; Rao, S.E.; Yasmeen, R.; Arshad, M.A. The Role of Intraarticular Platelet Rich Plasma (PRP) Injection in Patients with Internal Knee Derangements. *J. Coll. Physicians Surg.—Pak. JCPSP* **2015**, *25*, 699–701. [[PubMed](#)]
45. Betancourt, J.P.; Murrell, W.D. Leukocyte-Poor Platelet-Rich Plasma to Treat Degenerative Meniscal Tear: A Case Report. *J. Clin. Orthop. Trauma* **2016**, *7*, 106–109. [[CrossRef](#)]
46. Xiao, W.-F.; Yang, Y.-T.; Xie, W.-Q.; Liu, D.; He, M.; Cai, Z.-J.; Yu, D.-J.; Li, Y.-S.; Wei, L.-C. Effects of Platelet-Rich Plasma and Bone Marrow Mesenchymal Stem Cells on Meniscal Repair in the White-White Zone of the Meniscus. *Orthop. Surg.* **2021**, *13*, 2423–2432. [[CrossRef](#)]
47. Wang, Y.; Yao, C.; Yang, Z.; Guo, W. Clinical efficacy of platelet- rich plasma as adjuvant therapy in patients undergoing arthroscopic repair of meniscal injury. *J. Int. Med. Res* **2020**, *48*, 0300060520955059. [[CrossRef](#)]
48. Chahla, J.; Cinque, M.E.; Piuze, N.S.; Mannava, S.; Geeslin, A.G.; Murray, I.R.; Dornan, G.J.; Muschler, G.F.; LaPrade, R.F. A Call for Standardization in Platelet-Rich Plasma Preparation Protocols and Composition Reporting: A Systematic Review of the Clinical Orthopaedic Literature. *J. Bone Joint Surg. Am.* **2017**, *99*, 1769–1779. [[CrossRef](#)]

49. Amin, I.; Gellhorn, A.C. Platelet-Rich Plasma Use in Musculoskeletal Disorders: Are the Factors Important in Standardization Well Understood? *Phys. Med. Rehabil. Clin. N. Am.* **2019**, *30*, 439–449. [[CrossRef](#)]
50. Anitua, E. Plasma Rich in Growth Factors: Preliminary Results of Use in the Preparation of Future Sites for Implants. *Int. J. Oral Maxillofac. Implant.* **1999**, *14*, 529–535. [[PubMed](#)]
51. Kahn, R.A.; Cossette, I.; Friedman, L.I. Optimum Centrifugation Conditions for the Preparation of Platelet and Plasma Products. *Transfusion* **1976**, *16*, 162–165. [[CrossRef](#)] [[PubMed](#)]
52. McDermott, I.D.; Amis, A.A. The Consequences of Meniscectomy. *J. Bone Joint Surg. Br.* **2006**, *88*, 1549–1556. [[CrossRef](#)]
53. Chan, K.; Bhandari, M. Three-Minute Critical Appraisal of a Case Series Article. *Indian J. Orthop.* **2011**, *45*, 103–104. [[CrossRef](#)]
54. Beaufils, P.; Becker, R.; Kopf, S.; Matthieu, O.; Pujol, N. The Knee Meniscus: Management of Traumatic Tears and Degenerative Lesions. *EFORT Open Rev.* **2017**, *2*, 195–203. [[CrossRef](#)] [[PubMed](#)]
55. Beaufils, P.; Pujol, N. Management of Traumatic Meniscal Tear and Degenerative Meniscal Lesions. Save the Meniscus. *Orthop. Traumatol. Surg. Res. OTSR* **2017**, *103*, S237–S244. [[CrossRef](#)] [[PubMed](#)]
56. Peck, E.; Finnoff, J.T.; Smith, J.; Curtiss, H.; Muir, J.; Hollman, J.H. Accuracy of Palpation-Guided and Ultrasound-Guided Needle Tip Placement into the Deep and Superficial Posterior Leg Compartments. *Am. J. Sports Med.* **2011**, *39*, 1968–1974. [[CrossRef](#)]
57. Derian, A.; Amundson, J.; Abi-Aad, K.; Vasquez-Duarte, R.; Johnson-Greene, D. Accuracy of Ultrasound-Guided versus Palpation-Based Carpometacarpal Joint Injections: A Randomized Pilot Study in Cadavers. *Ultrasound Leeds Engl.* **2018**, *26*, 245–250. [[CrossRef](#)]
58. Roh, Y.H.; Hwangbo, K.; Gong, H.S.; Baek, G.H. Comparison of Ultrasound-Guided Versus Landmark-Based Corticosteroid Injection for Carpal Tunnel Syndrome: A Prospective Randomized Trial. *J. Hand Surg.* **2019**, *44*, 304–310. [[CrossRef](#)]
59. Kane, D. The Role of Ultrasound in the Diagnosis and Management of Psoriatic Arthritis. *Curr. Rheumatol. Rep.* **2005**, *7*, 319–324. [[CrossRef](#)]