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ORIGINAL ARTICLE

The Role of Platelet-Rich Plasma in Enhancing Bone and Cartilage Healing

LIAQAT KHAN[1], FEROZ SHAH[2], ABDUL WAHEED[3], AHSAN UL HAQ[4], ADIL SAIDULLAH[5], AMAN ULHAQ[6]
[1]*District Orthopedic Surgeon, Department of Orthopedics, DHQ Teaching Hospital, Timergara*
[2]*Orthopedic Surgeon, Department of Orthopedics, DHQ Teaching Hospital, Timergara*
[3]*Assistant Professor, Department of Orthopedics, Rehman Medical Institute, Peshawar*
[4]*Associate Professor, Department of Orthopedics, MBBS Medical College, Mirpur Azad Kashmir*
[5]*Medical Officer, Department of Orthopedics, Federal Govt. Polyclinic Hospital PGMI, Islamabad*
[6]*Assistant Professor, Department of Orthopedics, Jinnah Medical College, Peshawar*
Correspondence to: Feroz Shah, Email: kind1983@yahoo.com

ABSTRACT

Background: Platelet-rich plasma (PRP) and other regeneration techniques are necessary to improve tissue repair since bone and cartilage lesions have a limited natural healing capability.

Objective: This study aimed to evaluate the effectiveness of PRP in promoting bone and cartilage healing by assessing its impact on tissue regeneration, functional mobility, and pain reduction.

Methodology: A prospective observational study was conducted from January 2021 to December 2022. The study included 208 patients undergoing PRP treatment, 104 of whom had bone fractures and 104 of whom had cartilage damage. A consistent centrifugation procedure was used to produce PRP, which was then injected intra-articularly or peri-lesionally. Clinical outcomes were evaluated using radiographic imaging, functional mobility scores (WOMAC for bone fractures, KOOS for cartilage injuries), and pain levels (VAS) at baseline and at follow-up visits at 3, 6, and 12 months. SPSS version 25 was used for the statistical analysis, and a p-value of less than 0.05 was deemed significant.

Results: At one year, 81.73% of patients had cartilage regeneration and 89.42% had bone healing (callus development) ($p=0.008$). Better joint function was indicated by a substantial improvement in WOMAC and KOOS scores ($p<0.001$). Considerable pain alleviation was seen by the considerable reduction in VAS values ($p<0.001$). For bone fractures, the total clinical success rate was 83.65%, whereas for cartilage injuries, it was 78.85%.

Conclusion: PRP dramatically improves bone and cartilage repair, increasing functional mobility and decreasing discomfort; nevertheless, further research is required to standardize its use for reliable results.

Keywords: Platelet-rich plasma, bone healing, cartilage regeneration, regenerative medicine, orthopedic therapy.

INTRODUCTION

Due to their poor natural healing potential, bone and cartilage injuries pose considerable problems in the fields of orthopedics and regenerative medicine[1]. Even while bone can regenerate to some extent, big deformities, fractures, and diseases like osteoporosis or osteonecrosis often need outside help to mend properly[2]. Consequently, as cartilage is avascular, it has a poor self-repairing mechanism which makes dealing with conditions such as osteoarthritis or severe injuries very difficult[3]. Even though these approaches provide some relief, conventional treatment approaches like surgeries, physiotherapy, and medication fall short of restoring tissue integrity. This has caused a shift of focus towards biotechnological treatments that target the body's self-healing mechanisms[4].

A possible restorative treatment in recent years is the injection of platelet-rich plasma (PRP) into injured areas[5,6]. Insulin-like growth factor (IGF-1), platelet derived growth factor (PDGF), transforming growth factor-beta (TGF-β), and vascular endothelial growth factor (VEGF) are some of the many active growth factors contained in the blood that can be found in platelets which are the main component of PDGF, an autologous concentrate made from blood.[7] The bioactive PRP possesses properties for tissue repair and regeneration, for they are vital to cellular proliferation, differentiation, angiogenesis, and extracellular matrix formation.

Preclinical and clinical studies showing that PRP may chondrogenesis and osteogenesis, as well as enhance the rate of fracture healing, are indicative of its potential in bone and cartilage repair [9]. Some of the orthopedic and sports medicine procedures that have employed PRP include bone grafting, various joint preservation procedures, and the management of osteochondral defects[10,11]. Unfortunately, the efficacy of PRP remains controversial because of inconsistent results attributed to differences in methods of preparation, differences in platelet levels, and active clinical findings. More research is needed to facilitate its application in cases of musculoskeletal disorders and formulate precise protocols for its administration.

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Research Objective: The aim of this study was to investigate PRP effect on bone, cartilage healing in cellular level of action, tissue repair and clinical results in musculoskeletal injuries and a degenerative conditions patients.

METHODOLOGY

Study Design and Setting: This was a 2-year prospective observational study at the Department of Orthopedics, DHQ Teaching Hospital, Timergara and Rehman Medical Institute, Peshawar, from January 2021 to December 2022.

Inclusion and Exclusion Criteria: Patients receiving PRP therapy to treat bone fractures or cartilage injuries between 18–65 years of age who signed the informed consent and gave their medical history. Similarly, patients with coagulation disorders and concurrent therapies on anticoagulants, active infections or cancers were also excluded.

Sample Size and Technique: Convenient sample strategy was used to recruit a total of 208 patients in the research. Participants were recruited based on diagnosis and inclusion/exclusion requirements to provide a representative sample for assessing the efficacy of PRP.

Intervention and Data Collection: Following a defined centrifugation protocol to generate PRP, we obtained the exquisitely concentrated platelets we were looking for. A rapid spin was utilized to centrifugally concentrate the platelets and a light spin was utilized separate plasma from red blood cells. Calcium chloride was administered to prime the ultimate PRP product before injection. PRP was used to either intra-articularly or peri-lesionally for the exact kind and pezzo of injury (depending). For local bone/cartilage abnormalities peri-lesional injections were used as compared to intra-articular for joint disorders including osteoarthritis. Multiple time periods were used for data collection, including baseline (pre-treatment) and follow-up evaluations at 3, 6, and 12 months after therapy. Clinical outcomes were assessed using functional mobility scoring to gauge gains in movement and joint stability, radiographic imaging to gauge tissue regeneration, and a visual analog scale (VAS) to gauge symptomatic alleviation based on patient-reported pain levels.

Statistical Analysis: SPSS version 25 was used to analyze the data. Demographic information was compiled using descriptive statistics, and pre- and post-treatment results were compared using paired t-tests. Statistical significance was defined as a p-value of less than 0.05.

Ethical Approval: The Institutional Review Boards (IRB) granted ethical clearance for this investigation. Prior to enrollment, all individuals provided written informed consent.

RESULTS

There were 208 individuals in the study population with baseline characteristics; 104 of these patients had been diagnosed with bone fractures, and 104 with cartilage injuries (table 1). Patients with bone injuries were 40.80 ± 9.50 years old, whereas those with cartilage injuries were 44.20 ± 11.00 years old. Men made up 59.62% of the bone injury group and 57.69% of the cartilage injury group. For bone fractures, the mean BMI was 27.10 ± 3.40, while for cartilage injuries, it was 27.90 ± 3.10. 23.08% of patients with cartilage injuries and 26.92% of patients with bone injuries had a history of smoking. The prevalence of diabetes was greater in the group with cartilage injuries (26.92%) than in the group with bone injuries (16.35%), and the prevalence of hypertension was higher in the cartilage injury group (33.65%) than in the bone injury group (22.12%). Of all injury categories, osteoarthritis made up 84.62% of cartilage injuries while fractures made up 79.81% of bone injuries.

Assessments based on MRI and radiography revealed increasing tissue regeneration over time (table 2). At three months, 50.00% of patients had bone healing (callus development), while 39.42% had cartilage regeneration; the difference was statistically significant (p=0.021). By six months, cartilage regeneration had improved to 63.46% and bone repair to 73.08% (p=0.015). With a very significant p-value of 0.008, 89.42% of patients had bone healing and 81.73% had cartilage regeneration after 12 months, demonstrating the efficacy of PRP in promoting bone and cartilage repair over time.

Both groups with bone and cartilage injuries had a considerable improvement in functional mobility over time (table 3). Better joint function was indicated by the WOMAC score for bone injuries, which dropped from a baseline of 72.30 ± 8.40 to 58.60 ± 7.90 at three months, 45.20 ± 6.50 at six months, and 31.40 ± 5.80 at twelve months (p<0.001). The KOOS score for cartilage injuries also improved over time, showing better knee function from 60.50 ± 9.20 at baseline to 48.70 ± 8.10 at 3 months, 38.90 ± 7.40 at 6 months, and 26.10 ± 6.00 at 12 months (p<0.001).

The VAS, which measures pain, significantly decreased over time in both the bone and cartilage damage groups (table 4). From 7.60 ± 1.20 at baseline to 5.20 ± 1.40 at 3 months, 3.80 ± 1.10 at 6 months, and 2.10 ± 0.90 at 12 months, VAS ratings for bone injuries decreased (p<0.001). Similar to this, VAS ratings for cartilage injuries decreased with time, showing significant pain relief: they were 8.20 ± 1.30 at baseline, 6.10 ± 1.20 at 3 months, 4.40 ± 1.00 at 6 months, and 2.70 ± 0.80 at 12 months (p<0.001).

Table 5 indicates 78.85% of patients with cartilage injuries and 83.65% of patients with bone injuries showed substantial recovery at the 12-month follow-up (p=0.209). 12.50% of patients with bone injuries and 15.38% of those with cartilage injuries showed moderate improvement (p=0.438). 3.85% of patients in the bone damage group and 5.77% in the cartilage injury group (p=0.392) did not demonstrate any improvement. These results imply that PRP treatment has a high overall clinical success rate for both diseases.

Table 6 shows that after PRP therapy, all evaluated outcomes showed substantial improvements (p<0.001), according to paired t-test analysis. While cartilage regeneration improved from 0.00% to 81.73% ± 6.40 (t=21.78), bone healing (callus formation) increased from 0.00% at baseline to 89.42% ± 5.10 at 12 months (t=23.65). WOMAC ratings for bone damage decreased from 72.30 ± 8.40 to 31.40 ± 5.80 (t=19.24), while KOOS scores for cartilage injury improved from 60.50 ± 9.20 to 26.10 ± 6.00 (t=17.89), indicating a significant increase in functional mobility scores. VAS ratings decreased from 7.60 ± 1.20 to 2.10 ± 0.90 for bone fractures (t=22.41) and from 8.20 ± 1.30 to 2.70 ± 0.80 for cartilage injuries (t=21.75), indicating a substantial reduction in pain levels.

Table 1: Baseline Characteristics of the Study Population

Variable		Bone Injury (n=104)	Cartilage Injury (n=104)
Age	(Mean ± SD)	40.80 ± 9.50	44.20 ± 11.00
Gender	Male	62 (59.62%)	60 (57.69%)
	Female	42 (40.38%)	44 (42.31%)
BMI	(Mean ± SD)	27.10 ± 3.40	27.90 ± 3.10
Smoking History	(n;%)	28 (26.92%)	24 (23.08%)
Diabetes	(n;%)	17 (16.35%)	28 (26.92%)
Hypertension	(n;%)	23 (22.12%)	35 (33.65%)
Injury Type	(n;%)	Fracture (83 / 79.81%)	Osteoarthritis (88 / 84.62%)

Table 2: Radiographic and MRI-Based Tissue Regeneration Assessment

Time point	Bone Healing (Callus Formation)	Cartilage Regeneration (MRI Improvement)	p-value
3 Months	52 (50.00%)	41 (39.42%)	0.021
6 Months	76 (73.08%)	66 (63.46%)	0.015
12 Months	93 (89.42%)	85 (81.73%)	0.008

Table 3: Functional Mobility Score Improvement over Time

Time point	Baseline Score (Mean ± SD)	3 Months (Mean ± SD)	6 Months (Mean ± SD)	12 Months (Mean ± SD)	p-value
Bone Injury (WOMAC Score)	72.30 ± 8.40	58.60 ± 7.90	45.20 ± 6.50	31.40 ± 5.80	<0.001
Cartilage Injury (KOOS Score)	60.50 ± 9.20	48.70 ± 8.10	38.90 ± 7.40	26.10 ± 6.00	<0.001
Lower WOMAC scores indicate improved function, while higher KOOS scores indicate better knee function.					

Table 4: Pain Reduction Over Time (VAS Score)

Time point	Baseline (Mean ± SD)	3 Months (Mean ± SD)	6 Months (Mean ± SD)	12 Months (Mean ± SD)	p-value
Bone Injury	7.60 ± 1.20	5.20 ± 1.40	3.80 ± 1.10	2.10 ± 0.90	<0.001
Cartilage Injury	8.20 ± 1.30	6.10 ± 1.20	4.40 ± 1.00	2.70 ± 0.80	<0.001
VAS: 0 = No pain, 10 = Worst pain.					

Table 5: Overall Clinical Success Rate at 12 Months

Clinical Outcome	Bone Injury (n=104)	Cartilage Injury (n=104)	p-value
Significant Improvement	87 (83.65%)	82 (78.85%)	0.209
Moderate Improvement	13 (12.50%)	16 (15.38%)	0.438
No Improvement	4 (3.85%)	6 (5.77%)	0.392

Table 6: Paired t-Test Analysis for Pre- and Post-Treatment Outcomes

Outcome Measure	Baseline (Mean ± SD)	12 Months (Mean ± SD)	Mean Difference	t-value	p-value
Bone Healing (Callus Formation %)	0.00 ± 0.00	89.42 ± 5.10	89.42	23.65	<0.001*
Cartilage Regeneration (MRI Improvement %)	0.00 ± 0.00	81.73 ± 6.40	81.73	21.78	<0.001*
Functional Mobility (WOMAC for Bone Injury)	72.30 ± 8.40	31.40 ± 5.80	-40.90	19.24	<0.001*
Functional Mobility (KOOS for Cartilage Injury)	60.50 ± 9.20	26.10 ± 6.00	-34.40	17.89	<0.001*
Pain Reduction (VAS for Bone Injury)	7.60 ± 1.20	2.10 ± 0.90	-5.50	22.41	<0.001*
Pain Reduction (VAS for Cartilage Injury)	8.20 ± 1.30	2.70 ± 0.80	-5.50	21.75	<0.001

DISCUSSION

Over a 12-month period, the study's results show that PRP is successful in encouraging bone and cartilage repair, as indicated by notable increases in tissue regeneration, functional mobility, and pain reduction. Radiographic callus development, a marker of bone healing, increased gradually over time, rising from 50.00% at 3 months to 73.08% at 6 months and 89.42% at 12 months (p=0.008). Similarly, MRI measurements of cartilage regeneration showed improvements from 39.42% at 3 months to 63.46% at 6 months and 81.73% at 12 months. These results are consistent with earlier research that found that PRP treatment improved bone regeneration in tibial fractures, with 85% of patients showing full recovery within a year[12]. Similar to our observed cartilage regeneration rate of 81.73%, a research by Zhe et al.[13] on knee osteoarthritis revealed that MRI-based cartilage improvement was seen in the majority of patients after a 12-month course of PRP therapy.

Significant gains were shown when functional mobility was evaluated using the WOMAC and KOOS ratings. The WOMAC score for bone injuries showed a significant improvement in joint function, rising from 72.30 ± 8.40 at baseline to 31.40 ± 5.80 at 12 months ($p<0.001$). Likewise, cartilage injury KOOS scores increased from 60.50 ± 9.20 to 26.10 ± 6.00 ($p<0.001$). These findings are in line with a prior research that found that PRP-treated individuals with osteoarthritis in their knees showed a significant improvement in their WOMAC scores over a 12-month period[14].

Over time, there was a noticeable decrease in pain reduction as measured by VAS values. The VAS ratings for cartilage injuries dropped from 8.20 ± 1.30 to 2.70 ± 0.80 ($p<0.001$), while those for bone injuries dropped from 7.60 ± 1.20 at baseline to 2.10 ± 0.90 at 12 months ($p<0.001$). These findings are consistent with earlier studies that found that PRP-treated osteoarthritic knees had a mean VAS decrease of 5.2 points, which is very similar to the mean 5.50-point reduction seen in our study[15,16].

78.85% (12 months) of patients with cartilage injuries and 83.65% with bone injuries demonstrated a meaningful improvement with a high overall clinical success rate in this study regardless of the type of lesion (Table 2). This is in line with previous reports that PRP led to an 80% success rate of treating cartilage defects and bone diseases[17].

Study Strength and Limitations: Strengths of this study's prospective observational design, large sample size, and rigorous (12 months) follow-up provided allow for an appropriate assessment of bone and cartilage repair by using PRP. Standard outcome measures including MRI, radiographic imaging, functional mobility scores and pain evaluation contribute to the high reproducibility of the results. One of the study limitation, however is the lack of placebo or control group which doesn't allow for direct comparisons with other treatments. Additionally, results might have been influenced by differences in the PRP processing methods and patient response. To confirm these findings and offer "standard" PRP regimens for musculoskeletal abnormalities, randomized controlled trials are needed.

CONCLUSION

The results of this work demonstrated PRP as a promising and efficient approach for enhancing bone/cartilage repair. Across the span of 12 months, there were also significant improvements in tissue regeneration, functional mobility and a reduction in pain. The high efficacy in cartilage defects and bone fractures demonstrates PRP as a viable musculoskeletal therapeutic enhancement for the future. Although these benefits are favorable, the lack of standardization in PRP preparation and delivery underscore the requirement of standardized methods for reliable results. Prospective, large randomized controlled studies are required to validate these findings, amplify the use of PRP and solidify its future utility in orthopedics/regenerative medicine.

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