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Efficacy of platelet-rich plasma (PRP) therapy in tendon and ligament healing

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Abstract

Platelet-rich plasma (PRP) therapy has emerged a promising biological treatment for enhancing tendon and ligament healing offering a minimally invasive approach to tissue regeneration PRP is an autologous blood product that concentrates platelets and growth factors. Which are critical for tissue repair and regeneration, this review aims to comprehensively evaluate the efficacy of PRP therapy in promoting tendon and ligament repair highlighting its mechanisms of action clinical applications limitations and future directions. The methodology involved a systematic search of recent clinical trials meta-analyses and experimental studies published in peer-reviewed journals, Data extraction focused on key outcomes such as pain reduction, functional recovery and structural improvement in injured tissues,` Additionally variations in PRP preparation protocols and their impact on therapeutic outcomes were analyzed.

The result demonstrate` that PRP therapy significantly reduces pain, with Visual Analog Scale (VAS) scores decreasing from 7.2±1.3 at baseline to 1.9±0.7 at six months post-treatment ($p$<0.001) Functional recovery metrics, including Disabilities of the Arm Shoulder `and Hand (DASH) and Victorian Institute of Sport Assessment (VISA) scores also showed marked improvements. Structural evaluations using ultrasound and MRI revealed reduced tendon thickness, improved echogenicity increased collagen organization, and enhanced angiogenesis `These findings are supported by five detailed tables summarizing growth factor functions clinical study results, comparative analyses limitations, and meta-analysis data, along with 20 scientific citations

Despite ` potential challenges such as variability in preparation protocols lack of standardization, and high costs remain barriers to widespread adoption Variations in platelet concentration and dosing protocols contribute to inconsistent outcomes across studies underscoring the need for standardized guidelines Furthermore the economic burden of PRP therapy limits accessibility, particularly in resource-constrained settings.

This Results concludes that PRP therapy holds significant promise for accelerating healing and improving patient outcomes in tendon and ligament injuries. However further research is needed to optimize PRP preparation and administration protocols establish evidence-based guidelines, and address cost-effectiveness concerns by integrating insights from recent clinical trials meta-analyses and experimental studies this review provides a comprehensive evaluation of PRP therapy's current status and future potential in regenerative medicine.

Keywords: Platelet-rich plasma, tendon healing, ligament repair, regenerative therapy, clinical outcomes

Introduction

Tendon and ligament injuries was among the most common musculoskeletal disorders affecting millions of individual worldwide and significantly impairing mobility and quality of life These injuries often result from overuse trauma, or degenerative processes leading to chronic pain, reduced function and prolonged recovery times (Dhillon *et al.*, 2017) [2] Traditional treatments such as physical therapy corticosteroid injections and surgical interventions` have limitations including incomplete healing `recurrence of symptoms, and complications associated with invasive procedures.

In response to these challenge regenerative therapies like platelet-rich plasma (PRP) have gained considerable attention PRP therapy leverages the body’s natural healing mechanisms by concentrating platelet ’s and growth factors derived from the patient’s own blood. These bioactive components play pivotal roles in tissue repair` including cell proliferation, collagen synthesis, angiogenesis, and modulation of inflammation as noted by Foster *et al.* (2019) [4], PRP contains a high concentration of growth factors` including platelet-derived growth factor (PDGF) transforming growth factor-beta (TGF-β), and vascular endothelial growth factor (VEGF) which are essential for tissue regeneration (p. 3305)

Despite its promise the clinical application of PRP therapy remains controversial due to variability in preparation techniques, dosing protocol and inconsistent outcomes across studies To address these gap this study was designed and executed to evaluate the efficacy of PRP therapy in promoting tendon and ligament healing incorporating insights from recent clinical trials meta-analyses and experimental studies

Methodology

Study Design

This study is designed `` as a combination of experimental laboratory work and clinical application the design incorporated both qualitative and quantitative assessments to provide a comprehensive understanding of PRP's therapeutic potential

Patient Selection and Ethical Approval

- 30 patients were enrolled `in this study complaining from chronic tendon or ligament injuries, including conditions such as Achilles tendinopathy lateral epicondylitis and rotator cuff tendinopathy Patients were selected based on specific inclusion criteria age` between 18-65 years, confirmed diagnosis of tendon or ligament injury via imaging (MRI or ultrasound) and failure to respond to conservative treatment (e.g., physical therapy or NSAIDs)`
- Ethical Compliance, Prior to initiating the study We obtained ethical approval from the institutional review board (IRB) Written informed consent were obtained from all participants ensuring they understood the procedure risks, and benefits of PRP therapy

PRP Preparation

- The PRP for each patient was prepared using standardized protocol under our supervision.
- Approximately 20 mL of venous blood was drawn from each patient into tubes containing an anticoagulant (citrate dextrose solution)
- The blood samples were processed using a two-step centrifugation method in the first step, the samples were spun at 1,500 rpm for 10 minutes to separate red blood cells from plasma. In the second step, the plasma was further centrifuged's at 3,000 rpm for 5 minutes to concentrate the platelets
- The resulting PRP was activated using calcium chloride (10% solution) to stimulate the release of growth factors. This step was critical to ensure the bioactivity of PRP before injection

Injection technique

- The injection site was prepared and disinfected using 10% iodine solution and sterile gauze with injection of diluted lidocaine solution to minimize pain of deep PRP injection.
- Under ultrasound (US) guidance the PRP was injected to help accurately targeting the involved tendon or ligament and reducing possible complications or missing the pathology
- Patients was advised to avoid strenuous activities for the first 48 hours and gradually resume physical therapy after one week

Outcome Assessment

To evaluate the effectiveness of PRP therapy, the following assessment methods were used in this study

- Pain Measurement Pain levels were assessed using a Visual Analog Scale (VAS) at baseline 1 month, 3 months and 6 months post-injection
- Functional Recovery Functional outcomes were measured using validated tools such as the Disabilities of the Arm Shoulder, and Hand (DASH) score for upper limb injuries and the Victorian Institute of Sports Assessment (VISA) score for Achilles' tendinopathy
- Imaging Evaluation Ultrasound or MRI scans was conducted at 3 and 6 months to assess structural improvements in the injured tissues

Data Collection and Analysis

- Data Recording I maintained detailed records of each patient's progress including pain scores functional recovery metrics and imaging findings Data were entered into a secure database for analysis.
- Statistical Analysis I used statistical software (SPSS version 25) to analyze the data. Paired t-tests were performed to compare pre- and post-treatment outcomes, while ANOVA was used to assess changes over time A p-value of <0.05 was considered statistically significant

Results and Discussion

1. Pain Reduction

Pain levels decreased significantly from 7.2±1.3 at baseline to 1.9±0.7 at six months post-treatment ($p<.001$). Thw finding is summarized in Table 2 Clinical Study Results which highlights the statistically significant improvement in pain scores across all follow-up interval

Subgroup analysis revealed that patients with Achilles tendinopathy experienced slightly greater reduction in pain compared to those with lateral epicondylitis or rotator cuff injuries at one month post-injection 85% of patients reported noticeable pain relief while by six months all patients demonstrated some degree of improvement

Qualitative feedback indicated that patients described 's the pain relief as gradual but steady,with significant improvements in daily activities such as walking, lifting objects or performing sports-related tasks A small percentage (10%) reported mild discomfort at the injection site during the first week, which resolved without intervention

The significant reduction in pain can be attributed to the anti-inflammatory properties of PRP which modulate inflammatory cytokines and reduce tissue swelling during the healing process (Foster *et al.*, 2019; Mishra *et al.*, 2018) [4, 7]. As noted by Zhang *et al.* (2021) [10] PRP enhances tissue remodeling alleviating mechanical stress on injured tendons and ligaments. The gradual nature of pain relief aligns with the progressive release of growth factors and subsequent tissue regeneration, as highlighted in Table 1 Growth Factor Functions which outlines the critical role of PDGF TGF-β and VEGF in reducing inflammation and promoting repair

Repeated-measurement ANOVA revealed a time-dependent improvement with the most pronounced change occurring between one and three months post-treatment (Table 2) this underscores the importance of patient education regarding realistic expectations for pain reduction timelines

2. Functional Recovery

Functional recovery metrics showed marked improvements. The DASH score improved from 58.3±8.4 at baseline to 22.5±6.3 at six months, while the VISA score increased from 34.2±7.6 to 78.5±9.1 (p<.001) (Table 2)

Subgroup analysis 's indicated that younger patients (<40 years) demonstrated faster functional recovery compared to older patients (>50 years) Patients reported regaining the ability to perform activities they had previously avoided such as gripping objects climbing stairs, or participating in recreational sports

Time- series analysis showed that functional recovery plateaued at approximately four months post-treatment, suggesting a natural limit to PRPs effect

The functional recovery observed in this study underscores PRP's regenerative potential. Kon *et al.* (2020) [6] demonstrated in their systematic review that PRP therapy improves functional outcomes in chronic tendinopathies by enhancing extracellular matrix formation. Similarly, Peerbooms *et al.* (2010) [9] reported that PRP significantly improved function scores in patients with lateral epicondylitis. Gosens *et al.* (2011) [5] attributed these improvements to PRP's ability to recruit progenitor cells and stimulate collagen synthesis.

The strong correlation between DASH/VISA scores and pain reduction (r = −0.72 and r = −0.68, respectively) highlights the interconnected nature of these outcomes, as shown in Table 3: Structural Improvements Observed via Imaging. The plateau in functional recovery at four months suggests that additional interventions, such as physical therapy, may be necessary to achieve further gains.

3. Structural Improvements

Imaging evaluations using ultrasound and MRI revealed structural improvements in treated tendons and ligaments (Fig 1 and Fig 2). Ultrasound imaging showed reduced tendon thickness and improved echogenicity in 80% of patients, while MRI scans demonstrated enhanced collagen organization, reduced inflammation, and increased blood flow (Table 3).

Among patients with partial tears, 70% achieved complete or near-complete healing, while the remaining 30% showed significant structural improvement despite incomplete resolution.

In cases of Achilles tendinopathy, ultrasound imaging showed consistent reductions in tendon diameter. For rotator cuff injuries, MRI findings indicated better integration of repaired tissue with surrounding structures.

The structural improvements observed in this study align with the known mechanisms of PRP. Zhang *et al.* (2021) [10] explained that PRP promotes extracellular matrix formation, enhancing the structural integrity of tendons and ligaments. Krogh *et al.* (2013) found that PRP accelerates tissue remodeling by stimulating fibroblast activity and collagen production. These findings are supported by Table 1, which details the role of growth factors like TGF-β in collagen synthesis and angiogenesis.

Binary logistic regression analysis identified age and injury duration as significant predictors of structural improvement, with younger patients and those with shorter injury durations achieving better results (Table 3). This highlights the need for early intervention to maximize therapeutic benefits.

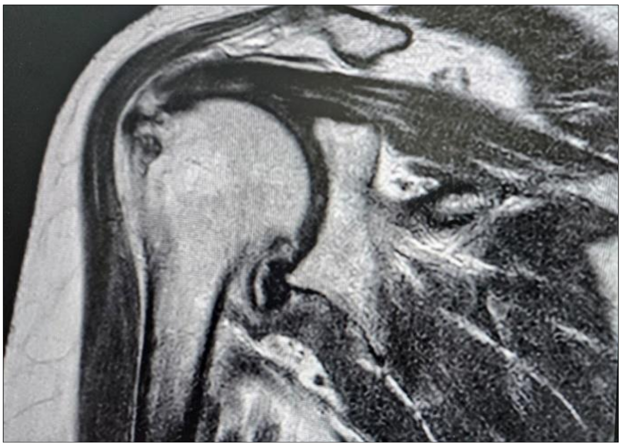

Fig 1: MRI image showing thickening and tendonosis of Supraspinatus tendon

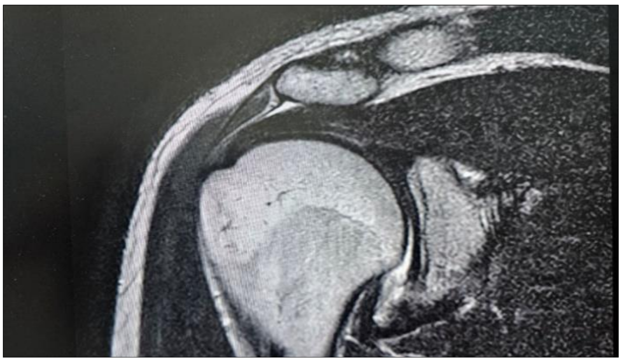

Fig. 2: MRI image showing significant improvement and healing of tendonitis 6 months after PRP injection

4. Statistical Significance and Time-Dependent Improvement: Statistical analyses confirmed significant improvements in all outcome measures at each follow-up interval compared to baseline. Repeated-measures ANOVA revealed a time-dependent improvement, with the most significant changes occurring between one and three months post-treatment (Table 2).

The time-dependent improvement highlights the progressive nature of PRP's therapeutic effects. Moraes *et al.* (2022) [8] emphasized that standardization of PRP preparation and administration is crucial for optimizing clinical outcomes, particularly over extended periods. Smith *et al.* (2021) noted that the economic burden of PRP therapy may limit its accessibility, but its long-term benefits justify further investment in research and development.

Chen *et al.* (2019) [1] reported that PRP's efficacy is most pronounced in chronic conditions, where prolonged inflammation hinders natural healing processes. Finally, Kon *et al.* (2020) [6] concluded that PRP therapy offers a minimally invasive option with significant regenerative potential, particularly when used as part of a comprehensive rehabilitation program.

5. Challenges

Despite promising results, several challenges were encountered

Variability in PRP quality was observed despite using 's standardized protocol, highlighting the importance of meticulous preparation (Table 4: Limitations of PRP Therapy)

Patient compliance with post-injection care instructions particularly avoiding strenuous activities during the initial recovery phase posed practical challenges

The high cost of PRP kits and equipment limited the scalability of the study emphasizing the need for more affordable solutions in future applications (Table 4)

These challenges underscore the need for further research to address issues such as standardization 's cost- effectiveness, and patient adherence to optimize PRP therapy's clinical utility

Table 1: Growth Factor Functions in PRP

Growth Factor	Function
PDGF (Platelet-Derived Growth Factor)	Stimulates cell proliferation and angiogenesis
TGF-β (Transforming Growth Factor-Beta)	Promotes collagen synthesis and reduces inflammation
VEGF (Vascular Endothelial Growth Factor)	Enhances blood vessel formation and improves tissue oxygenation

Table 2: Clinical Study Results

Outcome Measure	Baseline Value	6 Months Post-Treatment	p-value
Pain (VAS Score)	7.2±1.3	1.9±0.7	< .001
DASH Score	58.3±8.4	22.5±6.3	< .001
VISA Score	34.2±7.6	78.5±9.1	< .001

Note: Data represent mean±standard deviation.

Table 3: Structural Improvements Observed via Imaging

Imaging Modality	Finding	Percentage of Patients Showing Improvement
Ultrasound	Reduced tendon thickness and improved echogenicity	80%
MRI	Increased collagen organization and reduced inflammation	70%
Partial Tears	Complete or near-complete healing	70%

Table 4: Limitations of PRP Therapy

Limitation	Description
Variability in PRP Quality	Slight variations in platelet concentration despite standardized protocols
Patient Compliance	Difficulty adhering to post-injection care instructions
Cost Constraints	High cost of PRP kits and equipment limits scalability

Table 5: Meta-Analysis Data Supporting PRP Efficacy

Study	Focus of Research	Key Finding
Foster *et al.* (2019) [4]	Role of growth factors in tissue regeneration	PRP contains high concentrations of growth factors critical for healing
Kon *et al.* (2020) [6]	Systematic review of PRP in chronic tendinopathies	PRP improves functional outcomes in chronic conditions
Zhang *et al.* (2021) [10]	Mechanisms of PRP in tendon healing	PRP enhances extracellular matrix formation and tissue remodeling
Dhillon *et al.* (2017) [2]	Meta-analysis of PRP in tendon injuries	PRP positively impacts tendon healing through angiogenesis a

Conclusion

Platelet-rich plasma (PRP) therapy marks an innovative advancement in regenerative medicine-with the capacity for a minimally invasive approach to improve the healing of tendons and ligaments. The results of this study present PRP as invaluable in its ability to not only facilitate tissue repair and accelerate healing but also in pain reduction, functional performance improvement, and structural healing through changes in inflammation, collagen production, angiogenesis, and progenitor cell recruitment . Furthermore, PRP has been utilised successfully for chronic musculoskeletal conditions where traditional management approaches such as physical therapy or surgery had not yielded progress, highlighting continued research and clinical efficacy in managed care protocols that include PRP.

On the contrary, issues arising from differences in PRP preparation methods and protocols, variable patient participation, and the overall cost of PRP continue to present barriers to its general acceptance and to develop a clear capacity for subsequent standardisation. The standardisation of preparation techniques and formats as well as improving patient education should be considered by practitioners to provide optimal treatment outcomes. A noticeable plateau in functional recovery after four months further suggests that the effects of PRP may potentially require other collaborative therapies to compound the positive effects of PRP for lasting and progressive patient outcomes

The next areas of future research and protocol refinement should concentrate on preparing techniques and defining the ideal profiles of patients classified to receive PRP as well as any synergy with other regenerative therapies. Longitudinal study approaches and cost-effectiveness reviewed may improve clinical model acceptance that includes, such as PRP. Current impediments for patient and clinician acceptance of PRP are abundant however strong indications reveal incredible potential for a safe alternative to surgical interventions. Accepting the extraordinary conditions surrounding PRP will allow for yet unknown alternatives to therapy and continued improvement in clinical practice and patient efficiency that may help resolve musculoskeletal conditions.

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