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Newest approaches in ligament injury treatment: platelet-rich plasma (PRP) and stem cells

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Abstract

Background: Ligaments are strong connective tissues that connect bones to other bones, providing stability and supporting joint movement. Ligament injuries are a serious issue often experienced by athletes and active individuals, which can lead to pain, swelling, and reduced joint function. The treatment for ligament injuries varies depending on the severity of the injury and individual needs.

Purpose: To determine the effectiveness of these two methods in accelerating the healing process and reducing the risk of complications.

Method: A qualitative study using a literature review approach. Data collection was derived from various written sources, such as scientific journals, books, conference articles, and research reports. The data analysis technique involves several important steps: conducting extensive literature searches using relevant keywords, selecting literature based on its relevance and quality, thoroughly reading and understanding the content of the literature, recording important information, key findings, and interpretations presented by the authors. Once the data was gathered, the researcher performed synthesis and thematic analysis, organizing the findings into themes or categories aligned with the research topic.

Results: Out of 70 articles initially retrieved from Scopus, 9 articles were selected after undergoing a screening process based on predetermined criteria.

Conclusion: The use of PRP in the treatment of ligament injuries shows promising results in terms of accelerating recovery time and reducing patient pain. New therapies for ligament injury treatment using PRP and stem cells are highly promising in improving treatment outcomes and speeding up patient recovery.

Keywords: Injury; Ligament; PRP; Stem Cells.

INTRODUCTION

Activities performed incorrectly or with overuse are at risk of causing physical injuries. Physical injuries can disrupt the musculoskeletal system, which includes muscles, bones, joints, tendons, ligaments, and connective tissues that support and bind tissues and organs together (Dhuhairi, Israwan, Zakaria, & Hargiani, 2021).

Ligaments are strong connective tissues that link bones to each other, providing stability and supporting joint movement. Ligaments are made up of dense collagen fibers, allowing them to withstand

significant stress and load. One of the main functions of ligaments is to maintain balance and joint stability, enabling smooth and coordinated movement. Three primary bones often connected by ligaments during injury are the *femur* (thigh bone), *tibia* (shin bone), and *patella* (knee bone) (Ismail & Praptiningsih, 2022). The combination of these bones and the ligaments connecting them forms the complex structure of the knee joint, which is essential for everyday activities such as walking, running, and jumping.

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A common issue with Anterior Cruciate Ligament (ACL) injuries is instability in the knee joint, leading to difficulties in performing routine activities (Hafizh, 2022). One injury resulting from physical exercise and sports activities is ACL rupture (Santoso, Sari, Noviana, & Pahlawi, 2018).

The ACL is one of the important ligaments in the knee that connects the *femur* and *tibia*. It plays a crucial role in maintaining knee stability by preventing the *tibia* from shifting forward relative to the *femur* (Noviantari, 2022). This ligament is located at the front of the knee joint, closer to the *patella*. The ACL's structure allows the knee joint to move freely while providing the necessary stability for activities such as running and jumping. ACL injuries often occur due to sudden movements or changes in direction, such as in sports like football, basketball, and skiing.

The Posterior Cruciate Ligament (PCL) is also an important ligament that connects the femur and tibia, but it is located behind the ACL and crosses over it, forming an X-like structure within the knee joint. The PCL functions to prevent the tibia from sliding backward relative to the femur. Although PCL injuries are less common than ACL injuries, they can occur due to direct trauma to the knee, such as a car accident or a hard fall onto a bent knee. The PCL and ACL work together to ensure knee stability in various positions and movements (Kon, Filardo, Di Martino, & Marcacci, 2011).

An ACL injury, also known as an anterior ligament injury, is often very painful and can cause instability in the knee joint. ACL injuries can occur due to traumatic movements during sports, such as squatting, twisting, stopping movements, jumping, and sudden changes in speed (acceleration-deceleration) (Zukirman, 2024).

Common symptoms of an ACL injury include swelling, pain, and a feeling of instability in the knee, to the point where it feels like it is "giving out." Diagnosing an ACL injury usually involves a physical examination, knee stability tests, and imaging techniques like MRI (Collins, Alexander, & Barkatali, 2021). Treatment for ACL injuries varies depending on the severity and may include physical therapy, the use of assistive devices such as braces, and, in

many cases, ligament reconstruction surgery to restore knee function and stability.

Preventing ACL injuries involves strengthening the muscles around the knee and improving flexibility and coordination through proper physical training. Special exercise programs designed for ACL injury prevention often focus on strengthening the quadriceps and hamstrings, as well as balance and proprioception exercises to improve body awareness of joint position and movement. A good understanding of body mechanics and proper techniques in physical activities is also important for preventing ACL injuries (Adiarto, 2010). With a comprehensive prevention approach, the risk of ACL injuries can be minimized, allowing individuals to remain active and healthy.

Ligament injuries are a serious issue frequently encountered by athletes and active individuals, which can lead to pain, swelling, and joint dysfunction. Blood vessels affected by injury will undergo vasodilation or widening, and injuries in active individuals are usually sprains, which are tears in the ligament (Saputra, Kinanti, & Abdullah, 2022).

Treatment for ligament injuries varies depending on the severity of the injury and the individual's needs. Some traditional treatment methods involve physical therapy, the use of anti-inflammatory medications, and in some cases, surgery. However, with advancements in medical technology, more advanced treatments such as PRP therapy and stem cell therapy are gaining popularity and are considered more effective solutions for speeding up healing and regenerating damaged ligament tissue.

Platelet-rich plasma is one of the increasingly used treatment methods for ligament injuries by medical professionals. PRP contains many components that play a role in regenerative healing processes, including growth factors, chemotactic agents, and vasoactive agents (Dewi, 2021).

PRP involves taking a blood sample from the patient, which is then processed to separate the platelets and plasma. The platelet-rich plasma, which is rich in growth factors, is injected back into the injured area (Prabowo, Nurudhin, & Sari, 2023). Most PRP products contain a higher concentration of platelets compared to native blood, with a range of 2-12 times the baseline concentration (Indrasari,

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2023). However, some studies have identified platelet concentrations at 0.52x of the baseline level despite efforts to standardize protocols and preparation methods (Yaman & Kinard, 2022).

PRP contains high levels of growth factors and cytokines, which can initiate and repair tissue recovery by stimulating cell migration, cell proliferation, angiogenesis, and extracellular matrix synthesis (Siahaan & Suryawijaya, 2020).

The growth factors in PRP work to stimulate the body's natural healing processes and accelerate tissue regeneration. Research has shown that PRP is effective in reducing pain and improving joint function in patients with ligament injuries. This treatment is usually performed on an outpatient basis and carries minimal risk of side effects because it uses the patient's own blood.

Stem cell therapy is another treatment method that is increasingly used to treat ligament injuries. Stem cells are cells with the ability to develop into various types of cells in the body and play an important role in tissue regeneration processes (Mahendra, 2022). Stem cells are typically taken from the patient's bone marrow or adipose tissue, processed, and injected into the injured area. These stem cells work by promoting healing and the formation of new tissue in damaged ligaments. Stem cell therapy can accelerate recovery and improve joint function, particularly for ligament injuries that are difficult to heal using traditional methods. Mesenchymal stem cell therapy, sourced from the patient's own bone marrow (autologous), is an alternative corrective treatment for knee joint cartilage injuries (Merlina, Ardhanie, Kusnadi, & Lubis, 2015).

In addition to PRP and stem cell therapy, there are also other treatment methods that can be used to address ligament injuries. Physical therapy is an essential component in the recovery of ligament injuries. It involves specialized exercises designed to strengthen the muscles around the injured joint and improve flexibility. The use of assistive devices such as braces or splints is also common to provide stability to the joint during the healing process. In more severe cases, surgery may be required to repair torn or damaged ligaments. A combination of these methods often provides the best results in

restoring joint function and enabling patients to return to normal activities.

PRP and stem cell therapy show great potential in accelerating the healing process of ligament injuries, a condition that often requires a long recovery time and can disrupt daily activities. With the increasing number of ligament injuries, particularly among athletes and active individuals, this research aims to provide in-depth insight into how these two methods work, as well as the benefits and challenges associated with their use.

Although PRP is considered a relatively safe treatment option, it still yields controversial results due to the numerous differences in composition and techniques of PRP application, which leads to difficulties in determining its effectiveness (Marini & Forlino, 2012).

With an increased understanding of the biological mechanisms underlying injury healing and advancements in medical technology, the findings of this research are expected to make a significant contribution to clinical practice and help many patients recover more quickly and effectively. The success of this research could also encourage further studies that will enrich our knowledge of the use of regenerative therapies for various other medical conditions.

RESEACH METHOD

Qualitative research methodology using a literature review approach involves a systematic process for collecting, evaluating, and synthesizing relevant information from various written sources. This approach focuses not only on gathering descriptive data but also on uncovering patterns, themes, and in-depth relationships from previous research findings. It enables researchers to develop a comprehensive understanding of the studied topic and identify gaps in existing knowledge.

Data collection was derived from various written sources, such as scientific journals, books, conference articles, and research reports. Scientific journals served as the primary sources due to their peer-reviewed research findings, ensuring data accuracy and validity. Books written by experts in the field of medicine and ligament injury therapy were also significant as they provided more in-depth and

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comprehensive explanations. Additionally, conference articles and research reports offered the latest and innovative information, which might not yet be widely published in journals or books.

Data analysis techniques using a literature review approach involve several key steps. First, an extensive literature search is conducted using keywords relevant to the research topic, such as "PRP," "stem cells," and "ligament injury treatment." Next, the researcher selects literature based on its relevance and quality, ensuring that only credible and significant sources are included. The subsequent step involves thoroughly reading and understanding the content of the literature, noting important information, key findings, and interpretations provided by the authors.

Once the data is collected, the researcher conducts synthesis and thematic analysis. This process involves grouping findings based on themes or categories relevant to the research topic. For instance, findings related to the effectiveness of PRP (Platelet-Rich Plasma) and stem cells in accelerating ligament injury recovery are grouped and analyzed together. This thematic analysis helps identify consistent patterns and differences across the research findings, providing a clearer picture of the effectiveness and mechanisms of PRP and stem cells in treating ligament injuries.

From the initial 70 articles obtained from Scopus, 9 articles were selected after undergoing a screening process based on predetermined criteria.

RESEARCH RESULTS

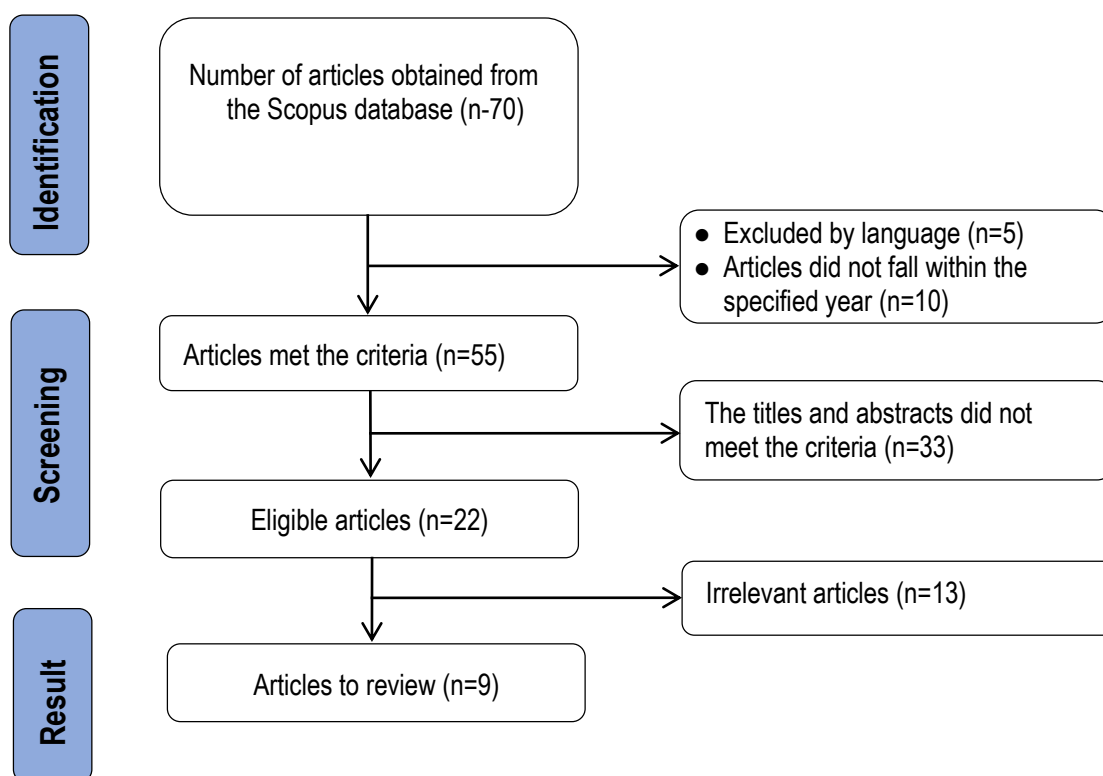


Figure 1. PRISMA Diagram

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Table 1. Brief Description of the Reviewed Articles

Author (Year) (Country)	Purpose	Method	Result
(Purba, 2020) (Indonesia)	To explore the potential of stem cell therapy for Alzheimer's disease.	Quantitative research involving pharmacological interventions to alleviate Alzheimer's disease symptoms.	This therapy is still in the exploratory phase and has not yet been proven fully effective as a treatment for Alzheimer's. Although initial studies show promise, particularly in improving cognitive function and reducing neurodegenerative symptoms, the long-term efficacy and safety of this therapy still require further investigation. Additionally, technical and ethical challenges, including the risk of side effects and the complexity of procedures, make stem cell therapy for Alzheimer's a hopeful prospect that necessitates more research before it can be considered a reliable and practical solution.
(Collins, Alexander, & Barkatali, 2021) (England)	To synopsise platelet-rich plasma (PRP) use in musculoskeletal pathologies through evidence-based assessment of the preparation, classification, mechanism of action and applications of PRP, thereby answering which PRP type is best for each clinical indication.	A literature review was conducted using the Medline, EMBASE, and Cochrane Review databases for all papers published between 1978 and 2019 that included the following key terms: "platelet-rich plasma" AND "orthopedics" AND ("classification" OR "mechanism of action" OR "preparation" OR "clinical applications").	The use of Platelet-Rich Plasma (PRP) in musculoskeletal pathology has been thoroughly evaluated through evidence-based assessments regarding the preparation, classification, mechanism of action, and clinical applications of PRP. Out of the 60 studies reviewed, it was found that various commercial kits for PRP preparation have different concentrations of components, but there is no consensus on the optimal component concentration. Although there are various classifications of PRP, none have been validated. PRP works through growth factors released from α-granules in platelets, which have been proven beneficial in healing, although concentrations that are too high can hinder the healing process. Several systematic reviews have shown the effectiveness of PRP in

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			tendinopathy, early osteoarthritis, acute muscle injuries, and in combination with rotator cuff repair and anterior ligament reconstruction. Leukocyte-rich PRP (L-PRP) is more beneficial for tendinopathy, while pure PRP (P-PRP) is more effective for cartilage pathology. However, there is a need for standardization of PRP research parameters to produce clearer findings and optimal clinical indications.
(Adiarto, 2010) (Indonesia)	To investigate the potential of stem cells for treating cardiovascular disease.	A descriptive qualitative study discussing stem cells in cardiovascular disease. The narrative description highlights the promising therapeutic potential in clinical trials, which has been further tested in laboratory research.	Revealing the potential of stem cells in cardiovascular disease therapy, which, although promising in laboratory and animal models, often fails to yield significant results in clinical trials. While stem cells have shown the ability to differentiate into various types of heart cells and improve heart function, their effectiveness in clinical therapy remains limited. Several challenges, such as the selection of the optimal stem cell type, delivery route, and local factors influencing cell placement, require further research. Basic research using animal disease models is crucial to address these challenges and provide a foundation for the development of more effective therapies in the future.
(Mahendra, 2022) (Indonesia)	To provide an introduction to cell-based therapy and its latest developments.	A qualitative descriptive study on cell-based therapy using two types of cells: immune cells and stem cells.	Discussing advances in cell-based therapy, which gained attention after James P. Allison and Tasuku Honjo won the 2018 Nobel Prize in Physiology or Medicine. These therapies, involving immune cells and stem cells, are recognized as future medical modalities with great potential, although they are still in the research stage. A key

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			discovery is the induced pluripotent stem cells (iPSCs) created by Shinya Yamanaka, which allow stem cell research without ethical concerns. This research also highlights the development of CAR-T cell therapy, which modifies CD8 cells to fight cancer more effectively.
(Prabowo, Nurudhin, & Sari, 2023) (Indonesia)	To study Mesenchymal Stem Cells in the Management of Rheumatoid Arthritis	Research on Mesenchymal Stem Cells in the Management of Rheumatoid Arthritis	RA is a chronic inflammatory disease with an unknown exact cause. RA is characterized by symmetrical polyarthritis in the joints of the hands and feet, along with the potential involvement of other organs. The disease involves an interplay of genetic factors, such as HLA-DR4, and external factors that trigger an autoimmune reaction. Research has identified five stages of RA development, with pathophysiology involving synovial cell hyperplasia and tissue damage caused by chronic inflammation. Genetic factors, including HLA-DR4 and PTPN22, contribute to RA risk, which occurs more frequently in women. Optimal therapy includes DMARDs and management of complications, such as macrophage activation syndrome.
(Kon, Filardo, Di Martino, & Marcacci, 2011) (England)	To search for a minimally invasive solution to improve the status of the chondral surface of the injured joint.	Analyzing published research to identify scientific evidence from preclinical studies or results obtained from the application of PRP in humans that support the efficacy of PRP and its use for treating tendon, ligament, cartilage,	The use of PRP for treating sports injuries has shown promising yet controversial results. PRP, which contains growth factors derived from platelets, has been proven to accelerate tendon healing in animal studies. However, results in humans remain varied. Some studies indicate that PRP can expedite recovery from tendon injuries such as Achilles and rotator cuff injuries and is effective for

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		and muscle injuries. The literature analysis reveals promising preclinical results but conflicting clinical findings for the treatment of sports injuries.	chronic tendinosis. Conversely, its outcomes are less favorable in chronic tendinopathy and ACL repair, showing results comparable to conventional treatments. PRP has the potential to enhance healing and reduce pain, but further research is needed to determine the optimal formulation, dosage, and application protocols.
(Utomo, & Hernugrahanto, 2018) (Indonesia)	To provide a fondation of PRF preparation and implantation for the healing of experimental defect of gastrocnemius muscle in an animal model.	Using the right hind limbs of twenty male New Zealand White Rabbits (weighing 2000 grams $\pm$ 500 grams). The rabbits were randomly divided into control and treatment groups.	The administration of platelet-rich fibrin (PRF) enhanced the healing of gastrocnemius muscle defects compared to the control group. Macroscopically, the defect surface in the PRF group appeared more regular and smooth, whereas the control group showed thicker scar tissue. Additionally, Pax7 expression in the PRF group was significantly higher at weeks two and four compared to the control group ($p < 0.05$). These findings indicate that PRF can accelerate muscle tissue regeneration and reduce scar tissue formation.
(Noviantari, 2022) (Indonesia)	To identify alternatives to trypsin in mesenchymal stem cell culture.	An assessment of reports or research articles on alternatives to trypsin in mesenchymal stem cell culture published in various scientific journals. The study began with collecting references from the internet, followed by a literature review of related materials. The reviewed literature was sourced from journals, books, and research reports from both domestic and	Human platelet lysate (hPL) and human platelet-rich plasma (hPRP) can replace fetal bovine serum (FBS) in mesenchymal stem cell (MSC) culture. hPL, which contains growth factors such as EGF and VEGF, enhances MSC proliferation and survival while reducing the risk of pathogen contamination and immunological reactions. hPRP, which is readily available and cost-effective, has also been proven to improve MSC proliferation and differentiation. Both alternatives offer advantages in terms of safety and efficiency compared to FBS.

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		international publications between 2011 and 2021. References prior to 2011 that remain relevant were also used as citations.	
(Ismail & Praptiningsih, 2022) (Indonesia)	To find out the effect determination of SHED and PRP hydrogels for fibroblast formation in alveolar bone regeneration in wistar rats	A laboratory experimental study with a post-test only control group design. The research sample consisted of 32 Wistar rats, randomly divided into 4 groups. Each group comprised 8 Wistar rats receiving different treatments: Group 1 received PRP hydrogel, Group 2 received SHED hydrogel, Group 3 received a combination of SHED and PRP hydrogel, and Group 4 received povidone-iodine.	The combination of stem cell hydrogel from human exfoliated deciduous teeth (SHED) and platelet-rich plasma (PRP) significantly increases the number of fibroblasts in the regeneration of the mandible bone in Wistar rats during orthodontic movement. This combination hydrogel is more effective than PRP hydrogel, SHED hydrogel, or povidone-iodine. The SHED and PRP combination accelerates bone matrix formation and enhances fibroblasts, whereas povidone-iodine functions only as an antiseptic without significantly affecting regeneration. The study also reveals limitations related to the viability of stem cells, which require immediate application after mixing.

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DISCUSSION

Platelet-Rich Plasma (PRP) treatment is an innovative therapy that utilizes autogenous blood plasma, which is plasma derived from the same individual undergoing the therapy (Purba, 2020). PRP consists of concentrated platelets suspended in plasma. To obtain PRP, blood is drawn from the patient and mixed with an anticoagulant to prevent clotting. The blood is then processed through centrifugation to separate its components based on their density, allowing platelets to be isolated and concentrated. This technique allows doctors to apply PRP in various clinical contexts with a better understanding of the therapy's mechanism of action.

PRP works by utilizing platelets, which are known to play a crucial role in the wound healing process. Platelets contain various growth factors and bioactive proteins that can stimulate tissue repair, enhance angiogenesis, and reduce inflammation (Utomo & Hernugrahanto, 2018). PRP, with its high platelet concentration, typically 2 to 12 times higher than the normal concentration in blood, can provide a more potent therapeutic effect compared to regular blood platelet counts. This concentration is achieved through proper centrifugation and careful preparation techniques.

Although PRP generally shows much higher platelet concentrations than regular blood, there are some variations in the final results obtained from various studies. Some studies report that the platelet concentration has not reached the optimal level, even achieving only 0.52 times the initial concentration despite following strict protocol standards. This suggests that other factors may influence the success of PRP preparation, such as the centrifugation technique, the type of anticoagulant used, and the individual's health condition.

The theory underlying the PRP treatment modality stems from a deep understanding of the human body's natural healing processes (Kon et al., 2011). When tissue is injured, the body's first response is to send platelets to the injured area. These platelets play a vital role in hemostasis, stopping bleeding by forming blood clots. However, their role does not end there. Platelets also contain growth factors and cytokines that are crucial for

initiating the healing of damaged tissue. These growth factors stimulate cell proliferation and accelerate healing by attracting stem cells to the wound area.

The stem cells attracted to the wound by the platelets have the ability to differentiate into various cell types required for tissue regeneration. They also secrete additional growth factors that support healing. This process creates an environment conducive to rapid and effective tissue repair. Additionally, stem cells possess immunomodulatory properties that can reduce inflammation in the wound area, making them an essential factor in speeding up the healing process. Therefore, platelets not only help stop bleeding but also play an essential role in tissue regeneration and recovery.

This basic science is then adopted into clinical practice in the form of PRP injections. PRP is a platelet concentrate obtained from the patient's own blood through centrifugation. After it is obtained, PRP is injected into the wound area to enhance the body's natural healing process. PRP, derived from the patient's own blood, carries a very low risk of allergic reactions or treatment rejection. The use of PRP has shown impressive results in treating various musculoskeletal injuries, such as ligament, tendon, and joint injuries (Collins et al., 2021).

Clinical studies have shown that PRP injections can accelerate healing and reduce pain in patients with ligament injuries, such as anterior cruciate ligament tears in the knee, tendon injuries like Achilles tendonitis, and joint issues such as osteoarthritis. PRP works by increasing the concentration of growth factors in the injured area, ultimately speeding up tissue regeneration. Additionally, PRP can reduce chronic inflammation often associated with musculoskeletal injuries, allowing patients to return to normal activity faster than with traditional treatment methods.

In clinical applications, PRP has been used in various medical fields, including orthopedics, sports medicine, dermatology, and plastic surgery. In orthopedics, PRP is commonly used to treat soft tissue injuries such as tendonitis and ligament tears. In dermatology, PRP is used for skin regeneration therapies, including facial rejuvenation and the

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treatment of chronic wounds. The mechanism by which PRP accelerates healing and tissue regeneration makes it an attractive option for many medical practitioners.

Ligament injury treatment using stem cells is a promising regenerative therapy approach, particularly in the field of orthopedics. This method has been developed with the goal of becoming the primary therapy with minimal risk of complications. Although several preclinical studies show its positive potential, further research is needed to fully evaluate its safety and effectiveness, particularly in the context of diverse orthopedic cases (Adiarto, 2010). Stem cell therapy offers great potential in musculoskeletal tissue regeneration. However, this approach remains controversial within the medical and scientific communities. Therefore, long-term research involving large population samples is required to provide strong evidence regarding the benefits and potential risks of this therapy.

In the context of orthopedics, ligament injury is a major issue that affects patient mobility and quality of life. The use of stem cells is expected to offer a more effective regenerative solution compared to conventional methods such as surgery or physical therapy. However, due to the complexity of ligament anatomy and biomechanics, a deeper understanding of the interaction between stem cells and ligament tissue is crucial to ensuring the long-term success of this treatment.

Stem cells can be classified based on their source, each offering unique potential in biology and medicine (Prabowo et al., 2023). First, totipotent cells are only found in early embryos and have the remarkable ability to differentiate into various types of cells necessary for forming a fully developed individual. Totipotent cells are an important starting point in embryonic development, allowing the formation of body cells and other essential components.

Second, pluripotent cells have the ability to differentiate into various intraembryonic cells but cannot differentiate into extraembryonic cells such as the placenta and umbilical cord. This means pluripotent cells have significant potential for regeneration and cell therapy, but they also have limitations that must be considered in their use in research and medical applications.

Third, multipotent cells allow differentiation into various types of cells within a single embryonic layer. The diversity of differentiation potential opens up significant opportunities for use in stem cell therapy, with the ability to produce cells such as osteocytes, adipocytes, and chondrocytes. This broadens the scope of stem cell therapy applications in various medical conditions, from bone diseases to soft tissue issues. Furthermore, unipotent stem cells are capable of producing only one specific type of cell but possess strong regenerative properties. For example, unipotent stem cells can generate specific cells in certain tissues, which is important for the recovery and structural repair of the human body.

Treating ligament injuries using stem cells is a promising area of research in the medical world today. Ligaments are connective tissues that link bones to bones in the human body, providing stability and supporting joint movement. Ligament injuries, such as anterior cruciate ligament tears in the knee, often require intensive treatment to accelerate healing and restore normal joint function. One intriguing new approach is the use of stem cells to repair damaged ligaments.

Stem cells are cells that have the ability to replicate and differentiate into various types of cells in the body, including ligament cells (Adiarto, 2010). Stem cells can be derived from various sources, including bone marrow or adipose tissue from the patient's own body. After being isolated, stem cells can be injected back into the injured ligament area to stimulate the body's natural healing process. This method aims not only to repair the damaged ligament structurally but also to reduce the risk of long-term complications such as joint stiffness or structural weakness. Early studies and cases suggest that the use of stem cells has the potential to improve the speed and quality of ligament healing, although challenges such as controlling cell growth and tissue integration remain the focus of intensive research. Therefore, although stem cell therapy offers a breakthrough in the treatment of ligament injuries, its application still requires careful, evidence-based approaches. Collaboration between researchers, orthopedic surgeons, and biomedical scientists will be key to overcoming these challenges and improving treatment techniques and outcomes for the benefit of patients in the future.

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CONCLUSION

This study provides a comprehensive review of two cutting-edge approaches for treating ligament injuries: Platelet Rich Plasma (PRP) therapy and Stem Cell therapy. The findings highlight that PRP therapy has shown encouraging results in reducing recovery time and alleviating pain for patients. Both PRP and Stem Cell therapies present significant potential for enhancing treatment effectiveness and accelerating the healing process for patients with ligament injuries.

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