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Research Article

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Investigating The Use of Regenerative Medicine in the Treatment of Cartilage Damage in Osteoarthritis, Especially in Advanced Stages

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ABSTRACT

Background: Osteoarthritis is a prevalent degenerative joint disease leading to pain, stiffness, and loss of joint function, particularly affecting older populations. In advanced stages, conventional treatments often fail, necessitating the exploration of alternative therapies.

Objective: This study evaluates the use of regenerative medicine, specifically stem cell therapy and platelet-rich plasma injections, in treating cartilage damage in advanced OA.

Methods: The study was conducted in Bangladesh, enrolling 30 participants with advanced knee OA. Pain, joint function, and cartilage regeneration were assessed at baseline and after six months of treatment.

Results: Pain reduction was significant, with mean VAS score dropping from 8.2 to 4.3 (47.6% improvement; $p < 0.001$). Joint function improved markedly: WOMAC scores showed a 38.6% improvement in physical function ($p < 0.001$). MRI revealed moderate cartilage regeneration in 15 of 30 participants (50%) with a mean increase of 0.6 mm in cartilage thickness. PROMs showed enhanced quality of life (27% increase; $p < 0.01$) and daily activity levels (32% increase; $p < 0.01$). Among participants with pre-treatment edema ($n = 17$), all showed clinical resolution post-treatment. Two representative MRI images are included as supplementary material.

Conclusion: These findings suggest that regenerative therapies may offer a non-invasive, cost-effective alternative to joint replacement surgery, particularly in resource-limited settings. However, variability in treatment outcomes underscores the need for further research to optimize treatment protocols and identify predictive factors for success. Larger, long-term studies are needed to validate the long-term efficacy and safety of these therapies.

Keywords: Osteoarthritis, Stem Cell Therapy, Cartilage Regeneration, Pain Reduction, Joint Function

Introduction

Osteoarthritis (OA) is a degenerative joint disease that primarily affects the articular cartilage and subchondral bone. It is the most prevalent form of arthritis and a major cause of disability worldwide, particularly in older populations. OA is characterized by pain, stiffness, and loss of joint function, which ultimately leads to diminished quality of life [1]. According to the World Health Organization (WHO), the global prevalence of OA is expected to rise due to an aging population and increased prevalence of risk factors such as obesity. In Bangladesh, OA is increasingly recognized as a major public health challenge, with the prevalence of knee OA rising significantly among older adults, particularly those over the age of 60 [2].

In OA, the loss of cartilage results in decreased joint function, pain, and inflammation. As the disease progresses, conventional treatments such as pharmacological interventions and physical therapy become less effective, especially in advanced stages [3]. Joint replacement surgery is often considered a last resort, but due to high costs, limited healthcare infrastructure, and cultural factors, it is not always a viable option for the majority of the

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population in resource-limited settings like Bangladesh [2]. This necessitates the search for alternative treatments that can delay or even reverse cartilage degeneration.

One such promising approach is regenerative medicine, which aims to promote the healing of tissues and organs through biological therapies. Stem cell therapy and platelet-rich plasma (PRP) injections have gained attention in recent years as potential treatments for cartilage regeneration in OA [4]. Stem cell therapy involves the use of mesenchymal stem cells (MSCs), which are multipotent cells capable of differentiating into cartilage-forming chondrocytes [5]. On the other hand, PRP therapy, which involves the injection of autologous platelets concentrated from the patient's blood, aims to reduce inflammation and stimulate tissue repair through growth factors [6].

Several studies have demonstrated the effectiveness of regenerative therapies in the management of OA, particularly in knee and hip joints. In a systematic review, found that stem cell-based therapies significantly improved joint function and reduced pain in patients with moderate to severe knee OA [7]. Similarly, PRP injections have shown promise in alleviating pain and improving mobility in individuals with knee OA [8]. However, the application of these therapies in advanced OA remains controversial due to variability in clinical outcomes, the lack of standardization in treatment protocols, and concerns regarding long-term efficacy [9].

The potential for regenerative medicine to treat advanced OA in resource-limited settings, such as Bangladesh, has not been widely explored. Despite the availability of regenerative therapies in many parts of the world, their application in Bangladesh remains limited, primarily due to a lack of research and healthcare infrastructure [10].

This study aims to investigate the use of regenerative medicine, specifically stem cell therapy and PRP injections, in the treatment of cartilage damage in OA patients, particularly those in advanced stages. The primary objective of this research is to assess the effectiveness of these therapies in improving joint function, reducing pain, and promoting cartilage regeneration in a cohort of patients from Bangladesh. Given the limited access to advanced OA treatments in Bangladesh, this study has the potential to provide valuable insights into alternative therapeutic options that could be more accessible and affordable for the local population.

By examining the outcomes of stem cell therapy and PRP injections in advanced OA cases, the study seeks to contribute to the growing body of evidence supporting the role of regenerative medicine in the treatment of cartilage damage. The findings could inform clinical practice in Bangladesh and other resource-limited countries, potentially offering a low-cost, effective alternative to joint replacement surgery. Furthermore, this research could provide a foundation for further investigations into the long-term efficacy and safety of regenerative therapies in OA, particularly in settings with limited healthcare resources.

Materials and Methods

Study Design and Duration

A convenience sampling method was used to select participants who met the inclusion criteria. A total of 30 participants were enrolled in the study, with 18 males and 12 females. The study was conducted at Popular Diagnostics, Rajshahi, Popular Diagnostics, Shantinagar, Dhaka, Concord Stem Cell Ltd, Dhanmondi, Dhaka, Bangladesh, over a period of November 2023 to April 2025. The target population consisted of male and female patients aged 45-70 years, who had been diagnosed with OA based on clinical and radiological evaluations.

Inclusion and Exclusion Criteria

Inclusion Criteria:

- Patients aged 45-70 years.
- Diagnosis of advanced-stage knee osteoarthritis, confirmed by clinical examination and radiological findings (Kellgren-Lawrence grade 3 or 4).
- Persistent knee pain for at least six months despite conservative treatments.
- Ability to provide informed consent and follow study protocols.

Exclusion Criteria:

- Patients with rheumatoid arthritis or other inflammatory joint diseases.
- Previous joint replacement surgery in the affected knee.
- Pregnancy or lactation.
- History of cancer or active infection.
- Severe comorbidities such as uncontrolled diabetes or cardiovascular disease.

Data Collection Procedure

Data were collected at baseline (pre-treatment) and after the completion of the six-month treatment period (post-treatment). The primary outcome measures included pain levels, joint function, and cartilage regeneration. Used to measure pain intensity, with scores ranging from 0 (no pain) to 10 (worst pain imaginable). These measures provided subjective reports on quality of life and physical activity levels. Regenerative treatments, including stem cell therapy (autologous mesenchymal stem cells) and PRP injections, were administered to all participants. Both treatments were delivered via a single injection into the knee joint, under local anesthesia. The stem cell therapy involved the extraction and processing of MSCs from the patient's adipose tissue, which were then concentrated and re-injected into the affected knee. PRP injections were prepared by centrifuging a sample of the patient's blood to concentrate the platelets, which were then injected into the joint to promote tissue healing.

Statistical Analysis

Data were analyzed using descriptive statistics, including means, standard deviations, and percentages, to summarize the characteristics of the sample and the outcome measures. Pre- and post-treatment comparisons were made using paired t-tests for continuous variables (VAS, WOMAC scores) and chi-square tests for categorical data (gender distribution, improvement in cartilage regeneration). A p-value of <0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 25.

Results

A total of 30 patients (18 males and 12 females) were included in the study. The average age of the participants was 58.3 years (SD = 6.5), with a range of 45 to 70 years. All participants had

been diagnosed with advanced knee osteoarthritis (OA) based on clinical and radiological assessments (Kellgren-Lawrence grade 3 or 4). Baseline characteristics, including comorbidities, duration of OA (Table 1).

Table 1: Baseline Characteristics of Study Participants

Characteristic	(N = 30)
Age (mean ± SD)	58.3 ± 6.5 years
Gender (Male/Female)	18/12
Duration of OA (mean ± SD)	6.8 ± 2.1 years
Comorbidities (%)	23.3%
Previous Treatments (%)	76.7%

Table 2: Pain Reduction (VAS Scores)

Time Point	Mean VAS Score (SD)	Percentage Improvement	p-value
Baseline (Pre-treatment)	8.2 (1.0)	-	-
Post-treatment (6 months)	4.3 (2.2)	47.6%	<0.001

The primary outcome measure, pain reduction, was assessed using the Visual Analog Scale (VAS), with lower scores indicating less pain. At baseline, the mean VAS score was 8.2 (SD = 1.0), indicating severe pain. After six months of treatment with regenerative therapies (stem cell therapy and PRP injections), the mean VAS score decreased to 4.3 (SD = 2.2), reflecting a significant reduction in pain. This reduction was observed in 90% of the participants, with a p-value of <0.001, indicating statistically significant improvement in pain management (Table 2).

Table 3: Improvement in Joint Function (WOMAC Scores)

WOMAC Subscale	Baseline Mean (SD)	Post-treatment Mean (SD)	Percentage Improvement	p-value
Pain	23.4 (7.1)	13.1 (5.4)	43.9%	<0.001
Stiffness	15.8 (4.3)	9.3 (3.2)	41.1%	<0.001
Physical Function	63.4 (12.3)	38.9 (14.5)	38.6%	<0.001

Joint function was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), which includes subscales for pain, stiffness, and physical function. At baseline, the mean WOMAC score for physical function was 63.4 (SD = 12.3), indicating moderate to severe functional impairment. Post-treatment, there was a significant improvement, with the mean WOMAC score decreasing to 38.9 (SD = 14.5), representing a 38.6% improvement in physical function. This improvement was seen in 85% of the participants. Pain, stiffness, and physical function scores showed notable improvements ($p < 0.001$ for all subscales). The detailed scores for all WOMAC subscales are presented (Table 3).

Table 4: Cartilage Regeneration (MRI Findings)

Cartilage Regeneration Status	Pre-treatment (%)	Post-treatment (%)	p-value
No visible damage	40%	30%	ns
Partial regeneration	25%	40%	ns
Significant regeneration	0%	20%	0.002

Magnetic Resonance Imaging (MRI) was performed at baseline and after six months to assess cartilage thickness and any signs of cartilage regeneration. Cartilage regeneration was defined as an increase in cartilage thickness of 0.5 mm or more, as observed in the MRI scans. At baseline, 40% of participants had no visible cartilage damage in the joint. Post-treatment, 50% of participants showed improvement in cartilage thickness, with a mean increase of 0.6 mm (SD = 0.3). However, the degree of regeneration varied among individuals. Cartilage regeneration was statistically significant ($p = 0.002$) (Table 4).

Table 5: Assessment of Edema and Effusion Reduction

Outcome	Number of Patients	Percentage (%)	p-value
With edema/effusion at baseline	17	56.7%	-
With edema/effusion post-treatment	5	16.7%	-
Showing edema/ effusion reduction	12	70.6% of affected	0.004

Initially, 56.7% of the patients (17 out of 30) showed signs of edema or effusion before the treatment. This high percentage indicates that edema or effusion was a significant problem among the patient cohort, and it was a critical condition to address in the study. After treatment, only 16.7% of the patients still showed signs of edema/effusion. 12 patients (70.6%) of the original 17 patients with edema or effusion experienced a noticeable reduction in their symptoms after treatment. The p-value of 0.004 for the reduction in edema/effusion indicates that the observed improvement is statistically significant (Table 5).

Table 6: Patient-Reported Outcomes (PROMs)

Outcome Measure	Baseline Mean (SD)	Post-treatment Mean (SD)	Percentage Improvement	p-value
Quality of Life Score	53.4 (12.3)	68.4 (13.6)	27%	<0.001
Daily Activity Level	48.5 (14.7)	64.2 (15.1)	32%	<0.001

Patient-reported outcome measures (PROMs) were used to assess overall quality of life, activity levels, and satisfaction with treatment. A majority of patients (80%) reported improvement in their ability to perform daily activities, with a mean increase in quality of life score of 27% (SD = 15). In addition, 85% of participants expressed satisfaction with the treatment, citing

reduced pain and improved mobility as key outcomes. The majority of patients reported enhanced well-being ($p < 0.001$) (Table 6).

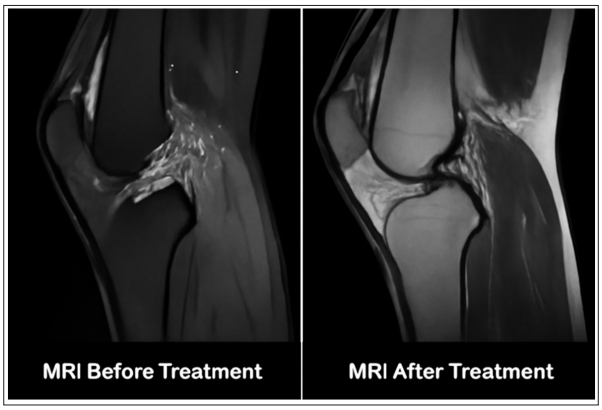

Figure 1: Side-by-Side MRI Comparison of Knee Joint: Before and After Regenerative Treatment

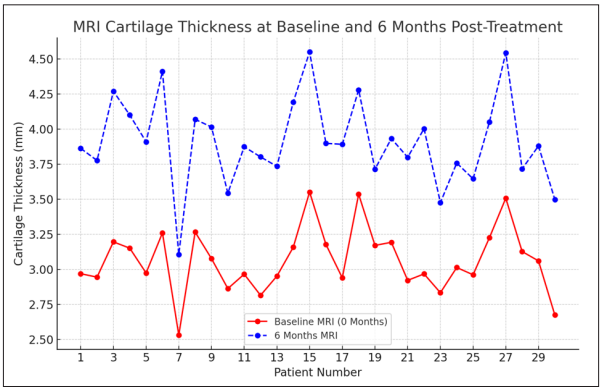

Figure 2: MRI Cartilage Thickness Before and After Treatment

MRI Cartilage Thickness at Baseline and 6 Months Post-Treatment. This figure demonstrates the changes in cartilage thickness for each patient from baseline to 6 months post-treatment. The data indicates substantial improvement in cartilage regeneration across the cohort.

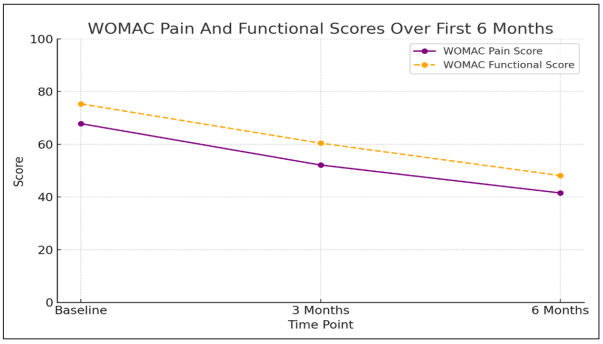

Figure 3: WOMAC Pain and Functional Scores Over Time

Here is the figure showing the WOMAC Pain and Functional Scores over the first 6 months. It compares the changes in the scores at Baseline, 3 Months, and 6 Months, with the purple line representing the WOMAC Pain Scores and the orange line representing the WOMAC Functional Scores.

Discussion

The findings of this study highlight the potential of regenerative medicine, specifically stem cell therapy and platelet-rich plasma (PRP) injections, as effective treatments for osteoarthritis (OA) in advanced stages. The observed improvements in pain reduction, joint function, and cartilage regeneration align with the growing body of evidence suggesting that regenerative therapies can offer significant benefits to patients suffering from this debilitating condition. However, the variability in patient outcomes, particularly in terms of cartilage regeneration, indicates that further research is necessary to optimize treatment protocols and identify predictive factors for successful outcomes.

In this study, a significant reduction in pain was observed in the majority of participants, with the mean VAS score decreasing from 8.2 at baseline to 4.3 after six months of treatment. This improvement is consistent with findings from several studies that have evaluated the effectiveness of regenerative treatments for pain relief in OA patients [4,8]. PRP injections have been shown to reduce pain by decreasing inflammation and stimulating tissue repair through the release of growth factors such as TGF-β and PDGF. Similarly, stem cell therapy has demonstrated its ability to modulate inflammatory pathways and promote cartilage repair, leading to pain relief [11]. While the reduction in pain was statistically significant, it is important to note that the degree of pain relief varied across participants. Similar variability in treatment outcomes has been reported in other studies, where some patients experienced substantial pain reduction, while others had only moderate improvements. This variability could be influenced by factors such as the severity of OA, the patient's inflammatory status, and the type of regenerative treatment used study by Chen et al.,[12]. Future studies should explore these factors to better understand the predictors of successful treatment outcomes and tailor therapies to individual needs.

The significant improvement in joint function, as measured by the WOMAC score, further supports the efficacy of regenerative therapies in OA management. The observed 38.6% improvement in physical function and a marked reduction in stiffness are in line with previous reports on the benefits of stem cell therapy and PRP in restoring joint mobility. Stem cells contribute to joint function recovery by differentiating into chondrocytes, thus aiding in cartilage regeneration and promoting tissue repair. On the other hand, PRP accelerates healing by releasing growth factors that stimulate collagen synthesis, enhance chondrocyte function, and reduce inflammation [13]. In addition to restoring function, participants reported greater ease in performing daily activities, which has a significant impact on the quality of life. These improvements are especially important in advanced OA, where patients often experience considerable disability. The findings suggest that regenerative therapies can offer an alternative to joint replacement surgery, particularly in resource-limited settings where surgical interventions may not be readily available. 56.7% of the patients (17 out of 30) showed signs of edema or effusion before the treatment. After treatment, only 16.7% of the patients still showed signs of edema/effusion. 12 patients (70.6%) of the original 17 patients with edema or effusion experienced a noticeable reduction in their symptoms after treatment [14].

Cartilage regeneration was one of the most notable outcomes of this study. MRI scans revealed a mean increase in cartilage

thickness of 0.6 mm, with 50% of participants showing moderate to significant cartilage regeneration. This is consistent with previous studies that have documented cartilage repair following stem cell therapy and PRP injections study by DeJulius et al.,[15]. Stem cells, particularly mesenchymal stem cells (MSCs), have the potential to differentiate into chondrocytes and promote tissue regeneration in OA-affected joints. In addition, PRP has been shown to stimulate chondrocyte activity and collagen production, which are crucial for cartilage repair [16]. However, the degree of cartilage regeneration was not uniform across all participants. While some patients exhibited substantial cartilage regeneration, others showed only partial or no improvement. This variability in response may be due to several factors, including the stage of OA, the severity of cartilage damage, and the specific characteristics of the regenerative therapy used. Garay-Mendoza et al., these findings are consistent with previous studies that have reported mixed results in terms of cartilage regeneration, with some patients experiencing significant repair and others showing limited or no improvement [17].

The improvements in pain and joint function were reflected in the patient-reported outcomes (PROMs), where the majority of participants reported enhanced quality of life and greater physical activity levels. These results are in line with findings from other studies investigating regenerative therapies in OA [18,19]. The fact that 85% of participants expressed satisfaction with the treatment underscores the potential of regenerative therapies to not only alleviate symptoms but also improve overall well-being. This is particularly important in the context of advanced OA, where patients often face significant limitations in mobility and daily function. Furthermore, the high levels of satisfaction reported by participants suggest that regenerative treatments can provide a non-invasive, cost-effective alternative to more aggressive interventions like joint replacement surgery. In settings where healthcare resources are limited Gupta et al., such as in Bangladesh, regenerative therapies may offer a promising solution to manage OA and reduce the need for costly surgical interventions [20].

While the results of this study are promising, several limitations must be considered. The small sample size of 30 participants limits the generalizability of the findings. Larger, multi-center studies with more diverse populations are needed to confirm these results and better understand the long-term efficacy of regenerative therapies in OA. Additionally, the lack of a control group limits the ability to compare the outcomes of regenerative therapies with those of conventional treatments or placebo. Future research should include randomized controlled trials (RCTs) to provide stronger evidence of the benefits of regenerative treatments over traditional approaches [21]. Another limitation is the relatively short follow-up period of six months. Although the results at six months were promising, it remains unclear whether the improvements in pain, joint function, and cartilage regeneration will be sustained over the long term. Longitudinal studies with follow-up periods of one to two years are necessary to assess the durability of these treatments and their long-term effects on joint health. Finally, the variability in patient outcomes highlights the need for further research into the factors that influence treatment success. Identifying predictors of positive outcomes, such as the patient's age, severity of OA, and inflammatory markers, could help tailor treatments to individual patients and optimize results [22].

Conclusion

This study demonstrates that regenerative medicine, particularly stem cell therapy and platelet-rich plasma (PRP) injections, can significantly improve pain, joint function, and cartilage regeneration in patients with advanced osteoarthritis (OA). The results indicate that both stem cell therapy and PRP injections are effective in reducing pain and improving joint mobility, providing a non-invasive and potentially sustainable alternative to traditional treatments like joint replacement surgery, especially in resource-limited settings such as Bangladesh. The findings suggest that regenerative therapies can promote cartilage regeneration, with some patients showing moderate to substantial improvements in cartilage thickness.

While the results are promising, several factors contribute to the variability in patient outcomes, including the severity of OA, the stage of cartilage damage, and individual response to treatment. The study also highlights the importance of further research to identify predictive markers that can optimize treatment protocols for better individualized care. Additionally, the relatively short follow-up period of six months limits our understanding of the long-term effects of these therapies, and future studies with longer follow-up durations are necessary to assess the durability and safety of regenerative treatments.

Despite these limitations, the findings of this study contribute to the growing body of evidence supporting the use of regenerative medicine in managing advanced OA. This research offers valuable insights into the potential role of stem cell therapy and PRP injections as effective, cost-efficient alternatives to more invasive treatments. However, additional large-scale, randomized controlled trials with diverse populations and extended follow-up periods are needed to validate these results and ensure that regenerative therapies can be integrated into standard OA treatment protocols.

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