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Innovative Approaches To Managing Osteoarthritis And Other Degenerative Joint Diseases: A Systematic Review

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Abstract

Background: Osteoarthritis (OA) and other degenerative joint diseases are leading causes of global disability, with traditional management strategies often failing to alter disease progression. This systematic review evaluates the efficacy and safety of innovative approaches, including biological therapies, pharmacological agents, and digital health interventions, for managing these conditions.
Methods: A comprehensive search was conducted across multiple electronic databases (PubMed, Scopus, Web of Science, Google Scholar) for studies published up to 2025. Included were clinical trials and systematic reviews evaluating innovative interventions for OA, reporting patient-centered outcomes such as pain, function, or disease modification. Data were extracted and synthesized narratively due to heterogeneity among studies. Methodological quality was assessed using appropriate tools such as the Cochrane Risk of Bias tool.
Results: Eleven studies met the inclusion criteria. Biological interventions like platelet-rich plasma (PRP) and umbilical cord-derived mesenchymal stem cells (UC-MSCs) showed promise for long-term symptom improvement and potential disease modification, with PRP demonstrating superiority over corticosteroids at one-year follow-up. The nerve growth factor inhibitor tanezumab provided rapid pain relief but was associated with safety risks, including rapidly progressive osteoarthritis. Digital health tools, including mobile apps and telerehabilitation, were found to be feasible, acceptable, and non-inferior to in-person care for improving pain and function.
Conclusion: Innovative approaches in OA management—including biologics, novel pharmaceuticals, and digital health strategies—offer significant potential beyond conventional care. A multimodal, personalized treatment model integrating these innovations is recommended to improve patient outcomes, balancing efficacy with safety. Future research should focus on large-scale randomized controlled trials with standardized protocols to confirm long-term benefits and safety profiles.

Introduction

Background

Osteoarthritis (OA) and other degenerative joint diseases represent some of the most prevalent chronic musculoskeletal disorders globally, contributing significantly to disability, healthcare costs, and reduced quality of life. These conditions are primarily characterized by the progressive breakdown of articular cartilage, changes in subchondral bone, and synovial inflammation. With an aging population and rising obesity rates, the prevalence of OA and related degenerative joint disorders continues to grow, making them major public health concerns. Traditional management strategies, while effective in alleviating symptoms, often fail to address the underlying mechanisms driving disease progression.

Conventional treatments for OA have largely focused on pharmacological interventions, such as nonsteroidal anti-inflammatory drugs (NSAIDs), analgesics, and corticosteroid injections, alongside lifestyle modifications including exercise and weight reduction. While these methods may provide temporary pain relief and functional improvement, they rarely prevent or reverse disease progression. Moreover, the long-term use of certain pharmacologic therapies is associated with significant adverse effects, such as gastrointestinal bleeding or cardiovascular risks. As a result, there has been an increasing demand for safer and more effective therapeutic strategies that not only control symptoms but also target disease mechanisms.

Over the past two decades, innovative approaches have emerged to revolutionize the management of OA and degenerative joint diseases. These approaches range from biological therapies, such as platelet-rich plasma (PRP) and stem cell treatments, to regenerative medicine techniques and novel biomaterials aimed at repairing cartilage damage. The use of mesenchymal stem cells, for example, has attracted substantial interest due to their potential for cartilage regeneration, immunomodulation, and reduction of inflammation. Similarly, PRP injections have shown promise in enhancing tissue repair by delivering concentrated growth factors directly into the affected joint.

In addition to biologics, advancements in pharmacological research have led to the development of disease-modifying osteoarthritis drugs (DMOADs). Unlike traditional symptomatic treatments, DMOADs are designed to slow or halt the degenerative process by targeting key molecular pathways involved in cartilage degradation, such as matrix metalloproteinases and inflammatory cytokines. Although most DMOADs remain under investigation, early clinical trials suggest their potential to transform OA management by providing long-term structural benefits.

Technological innovations have also played a critical role in modern approaches to joint disease management. For instance, image-guided intra-articular injections, robotic-assisted joint replacement surgeries, and three-dimensional printing of joint implants have enhanced precision and outcomes in orthopedic interventions. Furthermore, wearable technologies and digital health platforms are increasingly used to monitor patient mobility, pain levels, and treatment adherence, supporting more personalized and data-driven care strategies.

Non-pharmacological interventions are evolving as well. Exercise programs tailored with digital tools, neuromuscular stimulation, and physiotherapy approaches combined with virtual reality have been developed to improve mobility, reduce pain, and increase patient engagement. These novel rehabilitation methods highlight the importance of addressing OA and degenerative joint diseases through a multidisciplinary perspective that integrates physical, technological, and psychological components.

Nutraceuticals and dietary interventions have also emerged as adjunctive strategies. Compounds such as glucosamine, chondroitin sulfate, omega-3 fatty acids, and curcumin are being evaluated for their potential anti-inflammatory and cartilage-protective effects. While evidence remains mixed, the integration of nutritional therapies with standard care represents an innovative, holistic approach to joint disease management.

Another promising area of innovation is gene therapy, which aims to deliver therapeutic genes into joint tissues to regulate inflammatory pathways and stimulate cartilage repair. Preclinical studies have demonstrated the potential of gene-based treatments to modify disease progression by sustaining local production of anti-inflammatory mediators. Although still in early phases, gene therapy represents a frontier in the management of degenerative joint diseases, offering the possibility of long-lasting therapeutic effects.

The exploration of combination therapies is also gaining attention. By integrating biologics, DMOADs, physiotherapy, and nutritional strategies, researchers and clinicians aim to create comprehensive treatment protocols that address multiple aspects of disease pathology simultaneously. Such multimodal

approaches recognize the complexity of OA and degenerative joint diseases and attempt to provide individualized care tailored to patient needs.

In summary, the management of osteoarthritis and degenerative joint diseases is undergoing a significant transformation through innovative therapeutic and technological advancements. While conventional methods remain relevant, novel approaches focusing on regeneration, disease modification, and personalization of care are paving the way toward improved outcomes. A systematic review of these innovations is therefore timely, as it will consolidate the growing body of evidence, evaluate the efficacy and safety of emerging interventions, and provide insights into future directions for research and clinical practice.

Methodology

Study Design

This study was conducted as a systematic review aimed at identifying and synthesizing evidence on innovative approaches to managing osteoarthritis and other degenerative joint diseases. The review followed structured steps to ensure transparency, reproducibility, and comprehensiveness.

Search Strategy

A comprehensive search was carried out in multiple electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search covered studies published up to 2025. Search terms and keywords included combinations of: “osteoarthritis,” “degenerative joint disease,” “innovative therapy,” “regenerative medicine,” “stem cells,” “platelet-rich plasma,” “disease-modifying osteoarthritis drugs,” “gene therapy,” “biologics,” and “novel treatment.” Boolean operators (AND/OR) were used to refine the search. Additional manual searches were performed by screening the reference lists of relevant articles.

Eligibility Criteria

The inclusion criteria were as follows:

1. Studies that evaluated innovative or novel approaches in the management of osteoarthritis or degenerative joint diseases.
2. Clinical trials, cohort studies, case-control studies, and systematic reviews that provided patient-centered outcomes such as pain reduction, functional improvement, or disease modification.
3. Studies published in English.
4. Articles involving human subjects only.

Exclusion criteria were:

1. Studies conducted solely on animal or laboratory models.
2. Conference abstracts without full text.
3. Articles not reporting clinical outcomes related to management strategies.

Study Selection

All identified records were screened in two stages. First, titles and abstracts were reviewed to remove irrelevant studies. Second, full texts of potentially eligible articles were assessed against the inclusion and exclusion criteria. A total of 11 studies met the eligibility criteria and were included in the review.

Data Extraction

Data were extracted systematically from the included studies using a pre-designed data extraction sheet. The extracted information included:

- Author(s) and year of publication
- Country of study
- Study design
- Sample size and patient characteristics
- Type of innovative intervention used
- Comparator (if applicable)
- Outcomes measured (pain, function, progression, quality of life, adverse events)
- Main findings

Two reviewers independently performed data extraction, and any discrepancies were resolved by discussion until consensus was reached.

Quality Assessment

The methodological quality of the included studies was assessed using appropriate tools depending on study design. Randomized controlled trials were evaluated with the Cochrane Risk of Bias tool, while observational studies were assessed using the Newcastle-Ottawa Scale. Each study was rated as having low, moderate, or high risk of bias. Disagreements in assessment were resolved through consensus.

Data Synthesis

Findings from the included studies were synthesized narratively, as the heterogeneity of study designs, interventions, and outcome measures did not allow for meta-analysis. The narrative synthesis emphasized the type of innovative approach used, its clinical effectiveness, and reported safety outcomes. Common themes were identified and grouped under categories such as regenerative therapies, disease-modifying pharmacological agents, technological innovations, and adjunctive strategies.

Results

PRISMA Flow

A total of 756 records were identified through database searching and manual reference checks. After removing duplicates (212 records), 544 titles and abstracts were screened. Of these, 503 records were excluded as irrelevant to innovative interventions in osteoarthritis or degenerative joint diseases. 41 full-text articles were assessed for eligibility. 30 articles were excluded for reasons such as non-original research (n=12), lack of clinical outcomes (n=9), or insufficient methodological detail (n=9). Finally, 11 studies met the inclusion criteria and were included in this systematic review.

Table 1. Biological and Pharmacological Innovations

Study	Intervention	Sample (n)	Comparator	Main Outcomes	Key Findings
Ao et al. 2023	UC-MSC repeated injections	14	None (single-arm)	VAS, WOMAC, MOCART, SF-12	Safe, transient improvement (VAS ↓ from 6.0 → 3.5; WOMAC ↓ 26.0 → 8.5)
Yanke et al. 2024	BMAC during meniscectomy	83	Surgery without BMAC	IKDC, KOOS, PROMs	No significant differences overall; BMAC improved KOOS Sport & Symptoms MCID rates
Elksniņš-Finogejevs et al. 2020	PRP vs corticosteroid	40	PRP vs CS	VAS, IKDC, KSS	Both effective short-term; PRP superior at 1-year
Pretorius et al. 2022	PRP vs corticosteroid (bilateral OA)	29 (58 knees)	Within-subject	WOMAC, VNS	Both improved pain/function; no significant difference at 6 months
Berenbaum et al. 2020	Tanezumab (NGF inhibitor)	849	Placebo	WOMAC, PGA-OA	Tanezumab 5 mg > placebo in pain/function; RPOA risk higher with 5 mg

Schnitzer et al. 2020	Tanezumab titration	696	Placebo	WOMAC Pain & Function	Improvement within 1 week, sustained for 16 weeks
Li et al. 2021	Sprifermin (rhFGF18)	Review of trials	N/A	N/A	Cartilage thickness, safety

Biological approaches (stem cells, PRP, BMAC, growth factors) show potential for disease modification and longer-term improvements compared to corticosteroids. Tanezumab demonstrated rapid analgesic efficacy, though safety concerns (RPOA) temper enthusiasm. Sprifermin remains experimental but represents a candidate disease-modifying OA drug (DMOAD).

Table 2. Digital & Telerehabilitation Interventions

Study	Intervention	Sample (n)	Comparator	Main Outcomes	Key Findings
Weber et al. 2024	Join2Move app (PA + education)	60	Usual care	Pain, function, SUS	Significant pain reduction; usability rated "acceptable"
Arfaei Chitkar et al. 2021	Mobile app-based instruction	64 women	Routine care	WOMAC, SF-36	Improved pain, function, QoL (p=0.005)
Aily et al. 2023	Telerehabilitation circuit training	100	Face-to-face training	VAS, WOMAC, strength	Telerehab non-inferior to face-to-face; high adherence
Rose et al. 2023	Wearable sensors for gait	20	Lab-based	ICC, gait metrics	Reliable and feasible at-home monitoring

Digital health tools (apps, telerehabilitation, wearable sensors) show high feasibility and acceptability. Apps improved pain and function modestly, while telerehabilitation produced outcomes non-inferior to in-person therapy, supporting scalability. Wearables provide reliable remote monitoring, paving the way for personalized care.

Synthesis of Findings

- Biological interventions (stem cells, PRP, BMAC, sprifermin) show potential beyond symptomatic relief, with PRP demonstrating superiority over corticosteroids at long-term follow-up.
- Pharmacological agents like tanezumab rapidly reduce pain but carry notable safety risks.
- Digital and telerehabilitation strategies expand access to evidence-based care and maintain comparable effectiveness to conventional methods, suggesting strong future utility.

Discussion

This systematic review synthesized evidence from 11 innovative studies evaluating novel approaches to managing osteoarthritis (OA) and other degenerative joint diseases. The interventions ranged from biological therapies such as stem cells, platelet-rich plasma (PRP), and bone marrow aspirate concentrate (BMAC), to pharmacological agents like tanezumab and sprifermin, and finally to digital health strategies including mobile apps, telerehabilitation, and wearable sensors. Collectively, these approaches aim to address not only symptom relief but also functional restoration and potential disease modification.

Stem cell therapy remains a promising frontier in OA management. Ao et al. (2023) demonstrated that repeated intra-articular injections of umbilical cord-derived mesenchymal stem cells (UC-MSCs) were safe and associated with improvements in pain and function, as measured by VAS, WOMAC, and SF-12 scores. Importantly, no serious adverse events were reported, supporting the feasibility of repeated

administration in patients with moderate OA. However, the relatively small sample size and short follow-up necessitate larger trials to establish long-term efficacy.

In contrast, BMAC has been proposed as an adjunct to surgical management of meniscal tears with OA. Yanke et al. (2024) conducted a randomized controlled trial and found that BMAC administration during arthroscopic meniscectomy did not significantly improve IKDC or radiographic outcomes compared to surgery alone. Yet, improvements in KOOS Sport and KOOS Symptoms minimal clinically important difference (MCID) rates suggest possible benefits in specific domains. These findings highlight that not all biologics may yield broad outcomes, and their effects might be domain-specific.

PRP therapy, by contrast, has gained greater traction due to its anti-inflammatory and trophic properties. In a randomized trial, Elksniņš-Finogejevs et al. (2020) showed that while both PRP and corticosteroid injections improved pain and function in the short term, PRP provided superior long-term benefits up to one year. This aligns with Pretorius et al. (2022), who compared PRP and corticosteroids in bilateral knee OA patients. Although both interventions improved outcomes at all time points, PRP maintained slightly better results at six months, even though differences were not statistically significant. Together, these findings indicate PRP as a potentially superior long-term treatment compared to corticosteroids.

Beyond orthobiologics, pharmacological innovations like tanezumab, a nerve growth factor (NGF) inhibitor, have demonstrated rapid analgesic effects. Schnitzer et al. (2020) reported that tanezumab improved WOMAC pain and function within the first week, with efficacy maintained for 16 weeks. Similarly, Berenbaum et al. (2020) confirmed tanezumab's ability to reduce pain and improve function in a large phase III trial. However, they also reported a notable risk of rapidly progressive OA (RPOA), particularly with the higher 5 mg dose, raising concerns about its safety profile.

The case of tanezumab highlights a critical challenge in OA therapeutics: balancing efficacy with safety. While analgesic benefits are clear, the risk of accelerating joint degeneration presents a significant limitation to its clinical use. Regulatory bodies may remain cautious about approving such agents until long-term safety data are available. Thus, despite early promise, NGF inhibitors may remain limited in their application without substantial risk mitigation strategies.

Another pharmacological innovation, sprifermin (recombinant human FGF18), represents a potentially disease-modifying OA drug (DMOAD). According to Li et al. (2021), sprifermin stimulates cartilage growth and demonstrates tolerability without significant safety concerns. Although current studies indicate improvement in cartilage thickness, conclusive evidence regarding symptom relief and prevention of progression remains lacking. Large phase III trials are necessary to confirm its role as a true DMOAD.

Parallel to biologics and pharmacological innovations, digital health interventions have rapidly emerged as accessible and scalable treatment modalities. Weber et al. (2024) evaluated the Join2Move app, which integrates physical activity and education, and found it reduced pain significantly compared to usual care, with acceptable usability ratings. These findings suggest digital interventions can engage patients in self-management, though usability concerns highlight the need for better tailoring to patient preferences and abilities.

Similarly, Arfaei Chitkar et al. (2021) demonstrated that mobile app-based instruction significantly improved WOMAC and SF-36 physical function scores in female OA patients. This reinforces the role of app-based platforms not only in symptom reduction but also in enhancing quality of life. These interventions, when coupled with routine care, appear to augment outcomes effectively.

The scalability of telerehabilitation further supports digital solutions as practical alternatives to in-person care. Aily et al. (2023) showed that circuit training delivered via telerehabilitation produced non-inferior outcomes compared to face-to-face programs, with excellent adherence and high patient satisfaction. Such findings are particularly relevant in post-pandemic healthcare, where remote care models have become indispensable.

Wearable technologies add another layer of innovation by enabling objective, real-time monitoring of functional performance. Rose et al. (2023) demonstrated that wearable sensors reliably assessed gait and chair stand activities in home environments, with good test-retest reliability. These devices could support both clinical trials and personalized rehabilitation by providing continuous functional assessment in naturalistic settings.

Collectively, the digital interventions reviewed provide strong evidence that technology-assisted care can bridge gaps in accessibility, adherence, and monitoring. Unlike pharmacological or biologic therapies, digital solutions pose minimal safety concerns while empowering patient self-management.

However, challenges related to usability, digital literacy, and sustained engagement need to be addressed to maximize long-term effectiveness.

When comparing biological, pharmacological, and digital strategies, it becomes clear that each approach targets different aspects of OA management. Biologics such as PRP and UC-MSCs target cartilage health and long-term outcomes, pharmacological agents like tanezumab provide short-term pain relief but with safety trade-offs, and digital strategies emphasize function, accessibility, and patient empowerment. Integrating these approaches may provide a more comprehensive, multimodal management framework.

The heterogeneity of study populations, interventions, and outcomes across included trials underscores the need for standardized protocols. For instance, PRP preparation methods vary widely, influencing efficacy. Similarly, digital health studies differ in app design, interactivity, and adherence support. Without standardization, direct comparisons and meta-analyses remain challenging, limiting the ability to draw definitive conclusions.

Despite these limitations, the studies reviewed underscore a shifting paradigm in OA care. The emphasis is moving from traditional symptom management toward disease modification, patient-centered technologies, and holistic care models. This aligns with contemporary healthcare priorities, which emphasize accessibility, safety, and sustainability. The future of OA management may lie not in a single "silver bullet" therapy, but in combination approaches integrating biologics, safe pharmacological agents, and digital solutions.

Conclusion

Innovative approaches to OA management, including biological therapies (UC-MSCs, PRP, BMAC, sprifermin), pharmacological interventions (tanezumab), and digital health tools (apps, telerehabilitation, wearables), demonstrate significant potential to improve outcomes beyond conventional care. While biologics and digital solutions appear promising and relatively safe, pharmacological agents such as tanezumab highlight the need to balance efficacy with safety. Collectively, these studies suggest that the future of OA care lies in multimodal, personalized strategies that integrate novel therapies with patient-centered digital platforms.

Recommendations

1. Future research should prioritize large-scale, multicenter RCTs with standardized protocols to confirm the long-term safety and efficacy of biologics and pharmacological innovations.
2. PRP should be explored as a preferred injectable therapy over corticosteroids, given superior long-term outcomes.
3. UC-MSCs and sprifermin warrant continued clinical evaluation as potential DMOADs, with extended follow-ups to assess structural outcomes.
4. Tanezumab use should remain restricted to controlled clinical trials until safety risks such as RPOA are fully understood.
5. Digital health interventions (apps, telerehabilitation) should be incorporated into clinical pathways as adjunctive therapies, especially for enhancing accessibility and self-management.
6. Wearable sensors should be integrated into clinical practice for continuous, remote functional monitoring, aiding both rehabilitation and research.
7. Policymakers and clinicians should adopt a multimodal care model combining biologics, safe pharmacological agents, and digital solutions to provide personalized, cost-effective OA management.

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