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Regenerative Medicine in Veterinary Practice: Emerging Therapies and Future Perspectives

Manjali Rana[1]*, Bhuva Akash[2], Sakshi[3]
[1]MVSc, Division of Medicine, ICAR- Indian Veterinary Research Institute, Izatnagar, U.P.- 243122, India.
[2]PhD scholar Division of Veterinary public health and epidemiology, ICAR- Indian Veterinary Research Institute, Izatnagar-243122, U.P., India.
[3] PhD scholar Division of Medicine, ICAR- Indian Veterinary Research Institute, Izatnagar, U.P.- 243122, India.
*Corresponding author's email: ranamanjali@gmail.com
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Abstract

Veterinary regenerative medicine is an emerging field that aims to regenerate damaged tissues, improve organ function, and support recovery from chronic and degenerative diseases in animals. It includes diverse approaches such as mesenchymal stem cells (MSCs), platelet-rich plasma (PRP), autologous serum products, tissue engineering, gene therapy, and extracellular vesicle-based therapies. These treatments act through mechanisms including immunomodulation, growth-factor release, and stimulation of endogenous tissue repair. Regenerative therapies have shown promising applications in osteoarthritis, tendon and ligament injuries, bone and cartilage damage, chronic wounds, and other disorders, particularly in horses and companion animals. However, variations in biological sources, preparation methods, treatment protocols, and patient characteristics can result in inconsistent outcomes. Limited long-term clinical evidence, high treatment costs, specialized infrastructure, and regulatory concerns also restrict their wider adoption. Greater standardization, quality control, and well-designed clinical studies will be essential for establishing safe, effective, and reproducible regenerative therapies in routine veterinary practice.

Introduction

In recent years, medical science has shifted from conventional tissue repair toward tissue regeneration and restoration of normal biological function. Regenerative medicine aims to restore the function of diseased or damaged cells, tissues, and organs through a range of approaches, including cell-based therapies, biomaterials, growth factors, and tissue engineering. These approaches are designed to stimulate and coordinate the biological processes involved in tissue repair and regeneration. Regenerative medicine has therefore emerged as an important area of

research in both human and veterinary medicine. In veterinary medicine, it focuses on repairing and regenerating damaged tissues and organs, as well as managing chronic and degenerative diseases in animals (Voga, et al., 2020). Unlike conventional therapies, which often focus on controlling clinical signs reducing inflammation, or slowing disease progression, regenerative therapies aim to restore tissue structure and function by promoting cellular repair, replacement, and regeneration. Many regenerative therapies exert their effects through immunomodulation and paracrine activity, thereby regulating excessive inflammatory responses, preventing further tissue damage, and promoting endogenous repair.Consequently, regenerative medicine has become particularly relevant to the management of musculoskeletal injuries, osteoarthritis, tendon and ligament disorders, chronic wounds, and other conditions in veterinary patients.

Among the various approaches, mesenchymal stem cells (MSCs), platelet-rich plasma (PRP), and autologous serum products have gained increasing attention and clinical application, particularly in horses and companion animals such as dogs. The growing expenditure on pet healthcare, increasing awareness of companion animal wellness, and the shift toward personalized and regenerative approaches to veterinary care are contributing to the expansion of the field. Furthermore, the application of regenerative technologies in equine and livestock medicine offers additional opportunities for improving animal health, performance, welfare, and productivity. The increasing clinical adoption of these therapies has also contributed to the rapid growth of the veterinary regenerative medicine sector. The global veterinary regenerative medicine market is projected to increase from approximately USD 452.97 million in 2025 to USD 1,395.44 million by 2034, representing a compound annual growth rate (CAGR) of approximately 13.23%. While orthopedic applications in companion animals currently represent a major area of clinical use, the field is increasingly expanding toward systemic diseases, chronic wound management, regenerative dermatology, livestock applications, and technology-assisted therapeutic and diagnostic platforms.

Thus, veterinary regenerative medicine represents a rapidly evolving multidisciplinary field that integrates stem cell biology, molecular medicine, immunology, tissue engineering, biomaterials, and advanced therapeutic technologies. However, the therapeutic efficacy of therapies can vary considerably among individual patients. Factors such as age, systemic health, disease severity, hydration status, tissue environment, source of biological material, and processing or preparation techniques can influence the quality and clinical outcome of regenerative therapies. Standardization of cell isolation, culture, processing, dosage, administration routes, and quality-control parameters therefore remains an important challenge for

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the wider clinical application of these therapies (Guest et al., 2022). Continued research and standardization are essential to translate emerging regenerative strategies into safe, reproducible, and evidence-based clinical applications across different animal species.

Current Regenerative Medicine Treatments in Veterinary Practice:

Mesenchymal stem cell (MSC) therapy: MSCs are among the most widely studied regenerative therapies in veterinary medicine. They can be obtained bone marrow, adipose tissue, umbilical tissues, and dental pulp. Their therapeutic effects are not limited to direct tissue replacement; rather, they mainly act through paracrine and immunomodulatory mechanisms. MSCs release cytokines, growth factors, and extracellular vesicles that regulate inflammation, attract endogenous repair cells, and support tissue regeneration (Lin et al., 2026).

Platelet-rich plasma (PRP): PRP is an autologous blood-derived product containing a higher concentration of platelets than whole blood. Activated platelets release growth factors and cytokines that stimulate tissue repair, angiogenesis, and modulation of inflammation. PRP is widely used for osteoarthritis, tendon and ligament injuries, fracture healing, wound management, and periodontal disease (Garbin et al., 2020).

Autologous conditioned serum (ACS): ACS is prepared by incubating the patient's blood under specific conditions to stimulate the production of anti-inflammatory cytokines, particularly interleukin-1 receptor antagonist (IL-1Ra/IRAP). It is administered mainly for inflammatory and degenerative joint conditions, with established use particularly in equine orthopaedics.

Autologous protein solutions (APS): APS is a blood-derived biologic product is enriched with anti-inflammatory cytokines and growth factors. It aims to reduce inflammation and support tissue repair and has mainly been investigated for osteoarthritis and chronic musculoskeletal disorders in dogs and horses (Camargo Garbinet al., 2021).

Tissue engineering: Tissue engineering combines cells, biomaterial scaffolds, and signalling molecules to regenerate functional tissues. Tissue engineering widely used in cartilage repair, bone regeneration,tendon reconstruction, skin wound healing (Sharun, et al., 2025).

Gene therapy: Gene therapy involves modifying or delivering genetic material to alter cellular function and enhance tissue repair. Potential applications include enhancing regenerative proteins, reducing inflammatory mediators, and modifying disease-related pathways.

Extracellular vesicle and exosome-based therapies: Extracellular vesicles, including exosomes, are nanosized particles naturally released by cells, particularly mesenchymal stem cells. They contain proteins, lipids, RNA, and other signalling molecules that regulate cellular activity and

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tissue repair. Their ability to provide therapeutic effects without administering living cells makes them a promising cell-free approach in regenerative medicine (Heidarpour et al., 2024).

Challenges and Future Prospects

Despite its promising potential, regenerative medicine faces challenges such as lack of standardization, differences in stem-cell sources, isolation methods, culture conditions, cell dose and routes of administration. In addition, many regenerative therapies are supported by laboratory studies or small clinical trials, while large-scale, long-term studies are still limited. The high cost of treatment, requirement for specialized laboratories and trained personnel also restrict their widespread use. Safety, quality control and regulatory issues are other important concerns, particularly for stem-cell, exosome and gene-based therapies.

The future of veterinary regenerative medicine is promising, with advances in stem cells, exosomes, tissue engineering, gene therapy, and 3D bioprinting expected to improve treatment outcomes. Cell-free therapies such as extracellular vesicles may provide safer and more practical alternatives to cell-based therapies. Applications are likely to expand beyond orthopaedic disorders to chronic wounds, neurological, cardiovascular, reproductive, and systemic diseases.. Standardization and improved quality control will enhance the safety, efficacy, and consistency of regenerative treatments. With continued research, regulatory development, and reduced costs, regenerative medicine may become an important component of routine veterinary practice.

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