

A Review of Biomaterials in Veterinary Surgery: Current Applications and Future Directions

**Jassim M. Khalaf Albozachri, Hayder Mohammed Mohsen Al-Tomah,
Amaal M. Khudaier**

College of Veterinary Medicine, University of Kerbala, Kerbala, Iraq.
Corresponding author: jasim.khalaf@uokerbala.edu.iq

Received: 12/2/2026

Accepted: 22/2/2026

Published: 15/3/2026

Abstract--A large number of biomaterials are critical to contemporary veterinary surgery, offering new concepts in wound management for our pets to heal. New developments in a variety of materials, including metals, ceramics, polymers and natural materials, are discussed in the article together with their specific properties and medical applications as well as current challenges. Technologies like 3D-printed personalized implants and stem cell-based therapies have significantly improved on surgical precision and healing times for animals. But there are questions, including whether the materials can be safely handled and do not transmit diseases. Smart, custom biomaterials are in development, which may significantly improve the care we provide our pets. Current benefits, drawbacks, and potential future development of veterinary biomaterials for animals related to improved surgical outcomes are comprised in this review on recent advances.

Keywords — Biomaterials, Tissue engineering, Stem cell therapy, Orthopedic implants, Surgical outcomes.

INTRODUCTION

Similarly, biomaterials provide novel means to orthopedic support, wound repair and tissue replacement grafting as well as implant incorporation and are vital for advancing veterinary surgery. As in human medicine, sophisticated biomaterials have made their way into veterinary surgery during the last several decades. These materials should perform better, cause fewer problems and be biocompatible. Metals, ceramics, polymers, composites and custom- made scaffolds are currently widely employed by veterinarians to perform various surgical procedures (1,2).

As more people seek improved surgical options for their pets, researchers are zeroing in on biomaterials that will biodegrade naturally, encourage bone growth, help fight infection and promote recovery. Although titanium and stainless steel remained the most commonly used materials for orthopedic implants, 3D printing allowed to manufacture implants perfectly fitting to each animal's anatomy (3). The potential uses of biodegradable polymers such as polylactic acid (PLA), natural materials including collagen, and chitosan in tissue growth promotion and wound healing and drug

delivery are increasingly appreciated, the response to biomaterials varies among species due to differences in biomechanics, immune response, and healing capacity. For example, equine orthopedic implants must withstand high mechanical loads, whereas lightweight and rapidly integrating materials are preferred for avian bone repair. Similarly, wound healing dynamics differ between dogs, cats, and ruminants, influencing biomaterial selection (4,5)

Veterinary trauma management is evolving with it. Methods such as platelet-rich plasma (PRP), bioactive scaffolds, and mesenchymal stem cells (MSCs) are gaining popularity in veterinary practice. And because they help the body heal along with repairing damaged tissue, they often provide better outcomes than more conventional surgeries. With the convergence of new technology and what veterinarians were doing out in the field, further research needs to be conducted into how these materials might enhance animal experiments (6).

TYPES OF BIOMATERIALS IN VETERINARY SURGERY

Biomaterials fabricated from metals, ceramics, polymers, composites, and biological tissues form the core of modern veterinary surgery. They are used in applications from orthopedic and dental reconstruction to the repair of soft tissues and regenerative medicine. The central goal of these biomaterials is regeneration of function and integrity of injured tissue with biocompatibility, mechanical stability, and with minimal immunogenic response.

Orthopedic Implants:

Titanium and stainless steel are among the most frequently utilized metals in orthopedic implants due to their mechanical strength, corrosion resistance, and capacity to withstand high biomechanical stress. Titanium, particularly, is highly suitable for osseointegration due to its stable oxide surface that supports direct bonding of the bone. The recent advancements in material science have offered surface modification techniques such as plasma spraying, anodization, and nano-topographical patterning to enhance bone-implant contact and infection prevention. Patient-specific 3D-printed titanium implants have also transformed orthopedic surgery in small and large animals by offering planned anatomical fit and improved postoperative recovery. Such personalized implants have been shown to

minimize complications such as implant loosening and soft tissue inflammation (7).

Ceramic-Based Biomaterials:

Hydroxyapatite, bioglass, and zirconia are widely used in joint resurfacing, bone grafting, and dental rehabilitation owing to their superior osteoconductive and bioactive properties, hydroxyapatite contains a very comparable mineral phase of bone and therefore allows direct bone apposition with no deposition of fibrous tissue. Bioglass, on the other hand, develops a layer of hydroxycarbonate apatite when it comes into contact with body fluids, allowing for strong bonding to hard and soft tissues. Whereas ceramics are prone to brittleness and less suited to bearing loads, blending them with polymer or metallic matrices eliminates this drawback, providing composites with mechanical strength coupled with biological compatibility (8).

Polymeric and Natural Biomaterials:

Natural biopolymers such as collagen, gelatin, chitosan, and alginate and synthetic biodegradable polymers such as polylactic acid (PLA) and polyglycolic acid (PGA) are commonly used in wound healing, tissue scaffolds, and drug delivery (9). These materials slowly degrade in vivo, minimizing foreign body reactions and providing controlled release of therapeutic drugs or growth factors (9). Collagen-based scaffolds are most popular due to their similarity to the ECM structure and ability to facilitate cell proliferation and adhesion. Alginate hydrogels cross-linked with calcium ions provide a highly wet wound healing environment and also function as stem cell or antibiotic carriers (9).

Composite Biomaterials:

The ceramic-polymer composites take advantage of ceramics' bioactivity and polymers' processability and flexibility in producing materials with mechanical and biological characteristics mimicking that of natural bone. Their best mechanical strength, porosity, and bioactivity render them best suited for dental applications and bone graft substitutes, yet research continues to modify the microstructure and composition of these composites in an effort to achieve controlled degradation and ideal tissue integration (10).

Biologically Derived and Regenerative Materials:

Apart from traditional synthetic materials, biologically active agents that promote tissue regeneration have seen significant attention within veterinary practice. These types of materials such as platelet-rich plasma (PRP) and mesenchymal stem cells (MSCs) are embraced quickly into surgical and wound care protocols. PRP is a concentrated growth factor source that stimulates collagen synthesis and angiogenesis, and MSCs play a role in tissue remodeling and regeneration through paracrine signaling and differentiation potential (11). These bio-based therapies are increasingly being used in combination with scaffold materials to generate hybrid systems with both structural support and biological activation, biologically derived materials carry potential risks of pathogen transmission and immunogenic reactions; therefore, rigorous screening,

sterilization, and donor selection protocols are essential to ensure biosafety. (11).

CLINICAL APPLICATIONS

Due to their remarkable versatility and biocompatibility, the clinical use of biomaterials in veterinary surgery has expanded significantly in recent years. These materials are now considered indispensable tools across orthopedic, dental, maxillofacial, ophthalmic, and soft tissue procedures. Their integration into clinical practice has improved surgical outcomes, reduced postoperative complications, and enhanced the quality of life of animal patients.

Orthopedic Applications:

Composite materials and metals remain the mainstays of orthopedic surgery in animals. Titanium, stainless steel, and cobalt-chromium alloys are also employed extensively in surgical procedures such as tibial plateau leveling osteotomy (TPLO), fracture fixation, total joint replacement, and spinal stabilization due to their superior mechanical performance and resistance to corrosion. The development of intramedullary devices and locking plate systems has additionally increased stability in fixation, reducing the risk of failure of the implant, while newer technology in imaging such as computed tomography (CT), magnetic resonance imaging (MRI), and three-dimensional (3D) reconstruction allows for the surgeon to now individualize implants according to each patient's unique anatomical structure. The technology of 3D printing has enabled the production of customized implants and prostheses with accurate matching of bone defects to improve the fit of the implant, reduce surgery time, and decrease postoperative infection risk, clinical and experimental studies in canine orthopedic models have demonstrated reduced healing time, improved limb function, and lower complication rates following patient-specific implant placement (7,13). Customized titanium plates for reconstruction of long bones or mandible, for instance, have been found to achieve greater alignment accuracy and improved bone healing than standard plates (13).

Soft Tissue and Wound Healing Applications:

In the repair of soft tissues, biopolymer materials such as collagen, chitosan, and alginate play a central role in improving wound healing with decreased chances of infection. They are biodegradable scaffolds upon which cell migration, angiogenesis, and deposition of extracellular matrix take place. Collagen dressings provide a physiological blueprint for dermal remodeling, whereas chitosan possesses natural antimicrobial action that reduces bacterial infection and promotes tissue granulation, additionally, hybrid scaffolds of PRP with collagen or chitosan matrices have shown improved epithelialization and rapid healing of chronic wounds in dogs, cats, and horses (11).

Dental and Maxillofacial Applications:

In veterinary dentistry and veterinary maxillofacial surgery, bioglass and hydroxyapatite bioactive ceramics and resorbable polymer composites are the focal point of bone grafting, facial skeletal reconstruction, and socket preservation, hydroxyapatite blocks and granules are used to fill osseous defects due to trauma or tooth loss as a scaffold that integrates stepwise into

surrounding bone tissue. Resorbable polymer membranes made of PLA or PGA are utilized in guided bone regeneration (GBR) procedures where they act as a barrier to direct osteogenic cell migration and prevent soft tissue invasion. The synergy of bioactive and biodegradable properties yields mechanical stability and normal remodeling over a time frame (8).

Emerging Applications:

Apart from traditional uses, biomaterials increasingly are utilized for repairing tendons, constructing corneas, and regenerating nerves. Stem cells, antibiotics, or growth factors are increasingly evaluated for direct delivery by hydrogels and nanofiber scaffolds into the operative field. Stem-cell-seeded scaffolds represent an important step toward regenerative veterinary surgery because they enable not just tissue replacement but biological reconstruction of function.

In summary, the wide range of clinical uses for biomaterials from orthopedic devices to regenerative scaffolds itself makes them central to enabling advanced veterinary surgery. Continuous innovation in material design, imaging incorporation, and bioengineering can ensure even more clinical value in the near future (10).

FUTURE DIRECTIONS

Apart from providing mechanical support, advanced biomaterials with antibacterial, regenerative, and bioactive properties are currently being the subject of vast research. One of the main areas of research is the development of resorbable implants that will gradually be absorbed into the tissue when it heals without requiring secondary surgical removal and reducing chronic complication. These emerging materials are being engineered to match the rate of tissue regeneration, to offer structural support during the peak healing phase and then to break down without inducing inflammatory responses. Controlled release systems represent another area of investigation, which can deliver therapeutic drugs such as antibiotics, growth factors, and hormones to the surgical site itself. This not only enhances healing outcomes but also reduces systemic side effects and improves local tissue regeneration. For instance, biodegradable polymer scaffolds loaded with growth factor are able to induce osteogenesis and angiogenesis in bone deficits and antibacterial-loaded matrices can be used to prevent postoperative infection in both orthopedic and soft tissue surgeries (12).

The merging of stem cell therapy and biomaterial scaffolds represents one of the largest frontiers in regenerative veterinary surgery. Mesenchymal stem cells (MSCs), adipose-derived stem cells, or induced pluripotent stem cells (iPSCs) can be seeded onto biocompatible scaffolds to promote tissue regrowth and return of function. The hybrid systems offer structural support and biological activity, a milieu conducive to natural tissue remodeling and repair. Recent experimental and clinical studies involving canine and equine patients have reported improved bone regeneration and functional recovery following scaffold-based regenerative therapies the potential of these techniques in repairing bone, cartilage, tendon, and even complex facial structures in companion animals Despite promising outcomes, stem cell therapies raise regulatory and

ethical considerations. Standardization of cell sourcing, processing, and clinical application remains essential to ensure safety and compliance with veterinary regulatory frameworks. In particular, induced pluripotent stem cells (iPSCs) present concerns regarding genetic stability, tumorigenicity, and ethical oversight, long-term implant performance, including wear resistance, structural integrity, and chronic inflammatory responses, requires further investigation. Additionally, stem cell-based therapies carry potential tumorigenic risks, necessitating long-term safety monitoring (12).

CONCLUSION

Biomaterials' design and use have radically changed veterinary surgery, providing improved options for regenerative therapies, orthopedic reconstruction, and soft tissue repair. Metals, ceramics, polymers, composites, and biologically derived materials are the classes of biomaterials, each having unique properties that render them appropriate for particular clinical uses, from load-bearing implants to scaffolds for wound healing. Advancements in 3D printing and regenerative medicine have enabled the fabrication of patient-specific and functional implants, allowing for precise anatomical fitting, improved surgical outcomes, and reduced postoperative complications. Furthermore, the integration of stem cells with scaffold-based constructs and the use of biologically active drug delivery systems represent innovative therapeutic strategies that enhance tissue regeneration, accelerate healing, and improve overall recovery in companion animals.

Finally, the relentless advance of biomaterials and related technologies promises safer, more effective, and increasingly individualized surgery in veterinary medicine. This ongoing evolution is a fertile resource for clinicians, scientists, and students alike, informing developments and applications to come in the rapidly changing environment of veterinary surgical biomaterials. In spite of the advances, challenges remain, e.g., the optimization of biocompatibility, control of degradation rates, reduction of infection risk, and the transfer of in vitro data to the clinical environment. Future studies on intelligent, multifunctional, and custom-made biomaterials may continue to transform the veterinary surgery by providing the patients with safer, more effective and regenerative treatments.

Acknowledgements

N/A

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

- 1) Williams, D. F. (2019). Challenges with the development of biomaterials for sustainable tissue engineering. *Frontiers in bioengineering and biotechnology*, 7, 127. DOI: [10.3389/fbioe.2019.00127](https://doi.org/10.3389/fbioe.2019.00127)
- 2) Hench, L. L., & Polak, J. M. (2002). Third-generation biomedical materials. *Science*, 295(5557), 1014-1017. DOI: [10.1126/science.1067404](https://doi.org/10.1126/science.1067404)
- 3) Ison, S. H., Jarvis, S., Hall, S. A., Ashworth, C. J., & Rutherford, K. M. (2018). Periparturient behavior and

- physiology: further insight into the farrowing process for primiparous and multiparous sows. *Frontiers in veterinary science*, 5, 122. DOI: [10.3389/fvets.2018.00122](https://doi.org/10.3389/fvets.2018.00122)
- 4) Nair, L. S., & Laurencin, C. T. (2007). Biodegradable polymers as biomaterials. *Progress in polymer science*, 32(8-9), 762-798. DOI: [10.1016/j.progpolymsci.2007.05.017](https://doi.org/10.1016/j.progpolymsci.2007.05.017)
 - 5) Nasrollahzadeh, M., Sajjadi, M., Iravani, S., & Varma, R. S. (2021). Starch, cellulose, pectin, gum, alginate, chitin and chitosan derived (nano) materials for sustainable water treatment: A review. *Carbohydrate polymers*, 251, 116986. DOI: [10.1016/j.carbpol.2020.116986](https://doi.org/10.1016/j.carbpol.2020.116986).
 - 6) Cook, J. L., Smith, P. A., Bozynski, C. C., Kuroki, K., Cook, C. R., Stoker, A. M., & Pfeiffer, F. M. (2016). Multiple injections of leukoreduced platelet rich plasma reduce pain and functional impairment in a canine model of ACL and meniscal deficiency. *Journal of Orthopaedic Research*, 34(4), 607-615. DOI: [10.1002/jor.23054](https://doi.org/10.1002/jor.23054). Epub 2015 Oct 2.
 - 7) Gandapur, H. K., & Amin, M. S. (2022). Orthopaedics and additive manufacturing: the start of a new era. *Pakistan Journal of Medical Sciences*, 38(3Part-I), 751. DOI: [10.12669/pjms.38.3.5182](https://doi.org/10.12669/pjms.38.3.5182)
 - 8) Bose, S., Roy, M., & Bandyopadhyay, A. (2012). Recent advances in bone tissue engineering scaffolds. *Trends in biotechnology*, 30(10), 546-554. DOI: [10.1016/j.tibtech.2012.07.005](https://doi.org/10.1016/j.tibtech.2012.07.005).
 - 9) Dallaev, R. (2025). Smart and Biodegradable Polymers in Tissue Engineering and Interventional Devices: A Brief Review. *Polymers*, 17(14), 1976. DOI: [10.3390/polym17141976](https://doi.org/10.3390/polym17141976)
 - 10) Hutmacher, D. W. (2001). Scaffold design and fabrication technologies for engineering tissues—state of the art and future perspectives. *Journal of Biomaterials Science, Polymer Edition*, 12(1), 107-124. DOI: [10.1163/156856201744489](https://doi.org/10.1163/156856201744489).
 - 11) Fortier, L. A., & Travis, A. J. (2011). Stem cells in veterinary medicine. *Stem cell research & therapy*, 2(1), 9. DOI: [10.1186/scrt50](https://doi.org/10.1186/scrt50).
 - 12) Ivanovska, A., Wang, M., Arshaghi, T. E., Shaw, G., Alves, J., Byrne, A., ... & Barry, F. (2022). Manufacturing mesenchymal stromal cells for the treatment of osteoarthritis in canine patients: challenges and recommendations. *Frontiers in Veterinary Science*, 9, 897150. DOI: [10.3389/fvets.2022.897150](https://doi.org/10.3389/fvets.2022.897150).
 - 13) Duerr, F., & Elam, L. (Eds.). (2022). *Small Animal Orthopedic Medicine, An Issue of Veterinary Clinics of North America: Small Animal Practice, E-Book: Small Animal Orthopedic Medicine, An Issue of Veterinary Clinics of North America: Small Animal Practice, E-Book (Vol. 52, No. 4)*. Elsevier Health Sciences.