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Review article

Bridging the Infected Defect: Modern Strategies for Canine Fracture-Related Osteomyelitis

Khaled A. Abd El-Razik*[1] *and* *Abouelhag H. A.*[2]

[1] Animal Reproduction Dept., National Research Centre, Dokki, Giza, Egypt, 12622.
[2] Microbiology and Immunology Dept., National Research Centre, Dokki, Giza, Egypt, 12622.

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Abstract

Fracture-related bone infection (osteomyelitis) remains a challenging complication in canine orthopaedic surgery. This review synthesizes current evidence on the management of fracture-related infections (FRIs) in dogs, with emphasis on surgical debridement, implant management, systemic antibiotics, and emerging therapies. The standard of care achieves clinical success in many cases but is limited by biofilm formation. Local antibiotic delivery systems, such as resorbable calcium sulfate beads and antibiotic-impregnated hydrogels, provide high local drug concentrations. Bacteriophage therapy has shown superior biofilm clearance and callus formation compared to conventional antibiotics in a preclinical canine model. Advanced surgical techniques—circular external skeletal fixation, bone transport osteogenesis, and orthogonal plating with autografts—offer solutions for infected nonunions. This review highlights a multimodal, evidence-based approach and identifies priorities for future clinical research.

Keywords:
Canine, osteomyelitis, fracture-related infection, biofilm, local antibiotic delivery, bacteriophage therapy, Ilizarov technique, infected nonunion.

Introduction

Bone infection secondary to fracture repair constitutes a devastating complication in canine orthopaedic surgery. While historically reported to affect up to 31% of canine fractures (Johnson, 2020), contemporary incidence is likely lower owing to improved surgical techniques and perioperative protocols. The consequences of established osteomyelitis include implant loosening, delayed union or nonunion, septic arthritis, and in severe cases, limb amputation.

The management of canine FRIs has traditionally followed principles from human orthopaedic trauma: aggressive surgical debridement, fracture stabilization, and prolonged systemic antimicrobial therapy. However, the emergence of multidrug-resistant organisms and biofilm formation has rendered empirical regimens increasingly unreliable (González-Martín et al., 2022). Recent advances include local antibiotic delivery systems, bacteriophage therapy, and advanced fixation techniques. This review provides an evidence-based overview of current therapeutic strategies for canine FRIs.

1. Pathophysiology of Fracture-Related Bone Infection

Once bacteria gain access to the fracture site, they exploit devitalized tissue, compromised vascularity, and the presence of implants to establish infection. Biofilm formation is the pivotal event that transforms an acute infection into a chronic, treatment-resistant condition. Biofilms confer tolerance to host defences and antimicrobial agents (González-Martín et al., 2022). In a canine model of early-onset FRI, MRSA biofilms were consistently detected on fracture-fixation implants within 7 days of inoculation (Rigden et al., 2024).

Implants provide an ideal surface for bacterial adhesion and shield bacteria from phagocytic clearance. Implant retention carries a risk of infection persistence; biofilm formation frequently necessitates explantation after clinical union (Johnson, 2020).

2. Principles of Management

2.1. Antimicrobial Therapy

Antimicrobial therapy must be guided by culture and susceptibility results. Commonly isolated organisms include *Staphylococcus* spp., *Streptococcus* spp., and *Escherichia coli* with high resistance rates to some agents. The duration of systemic antibiotics remains debated. In a retrospective study of 34 dogs treated with antibiotic-impregnated poloxamer 407 hydrogel for orthopaedic surgical site infections, the overall infection clearance rate was 77%; each prior surgery reduced success by 25%, and multidrug resistance increased failure risk nearly eightfold (Smith et al., 2023).

Corresponding author: *Abouelhag H. A*
ha.elhag@nrc.sci.eg
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www.https://ricosbiology.net contact info@ricosbiology.net

2.2. Local Antibiotic Delivery Systems

Local delivery systems achieve high antibiotic concentrations at the infection site. Resorbable calcium sulfate beads are fully resorbable, eliminating the need for a second surgery. Cho et al. (2026) described successful treatment of an infected delayed union in a German Shepherd dog using vancomycin-impregnated calcium sulfate beads combined with bone morphogenetic protein-2–loaded hydroxyapatite and allograft, achieving clinical bone union by six weeks. Bird et al. (2024) reported successful pancarpal arthrodesis using gentamicin-impregnated bioabsorbable calcium sulfate beads in a dog with septic arthritis and osteomyelitis, with complete joint fusion at 12 weeks. In an earlier case series, tobramycin-impregnated calcium sulfate beads resolved osteomyelitis in five of five dogs with follow-up, and beads were no longer visible radiographically by five weeks after implantation (Fitzpatrick et al., 2005).

An alternative local delivery approach is the Vetlen pouch, an implantable diffusion reservoir connected to a subcutaneous tube. Jones and Hudson (2025) described this device enabling pet owners to administer daily amikacin therapy for 9–25 days, with infection resolution reported in five of six dogs.

2.3. Surgical Debridement and Fracture Stabilization

Adequate debridement of all devitalized tissue is critical. In a canine model of early-onset FRI, standard-of-care (debridement, implant retention, systemic antibiotics) was consistently associated with persistent biofilm, suggesting that implant exchange may be preferable even in early infections (Rigden et al., 2024).

For infected nonunions, circular external skeletal fixation (CESF) based on Ilizarov principles has demonstrated efficacy. In a retrospective study of 23 dogs, union was achieved in 20 cases (87%), with excellent or good midterm outcome in 17 (Cappellari et al., 2014). The Ilizarov technique also enables bone transport osteogenesis for segmental defects. Two canine cases treated with this approach achieved resolution of osteomyelitis and satisfactory fracture union (Ting et al., 2010). Orthogonal plating combined with corticospongious bone autograft has been used successfully for septic nonunion of the radius and ulna (Ferreira et al., 2025).

3. Emerging and Adjunctive Therapies

3.1. Bacteriophage Therapy

In a preclinical canine ulnar defect model with established *S. aureus* FRI, Schweser et al. (2025) compared 7 days of bacteriophage therapy to 6 weeks of parenteral antibiotics. Phage therapy was at least as effective as antibiotics and was superior in reducing bacterial colony-forming units per gram of tissue, promoting more robust callus formation (77.7% vs. 52.5% at 11 weeks), and achieving better biofilm clearance. These findings suggest that a short course of phage therapy may outperform prolonged antibiotic therapy, though clinical translation requires further study.

3.2. Biological Augmentation

Corticospongious bone autografts provide osteoconductive scaffolding and osteoinductive growth factors, enhancing bone healing in infected nonunions (Ferreira et al., 2025).

Bone morphogenetic protein-2 (BMP-2) has shown promise in promoting bone regeneration in challenging nonunions. Lee et al. (2024) reported successful surgical reconstruction of canine nonunion fractures using BMP-2-loaded alginate microbeads and bone allografts in two dogs, with excessive callus formation and early radiographic bone union. Massie et al. (2017) treated 11 nonunion fractures in nine dogs with compression resistant matrix infused with recombinant human BMP-2, achieving a median healing time of 10 weeks, with nine limbs returning to full function and two to acceptable function.

Platelet-rich plasma (PRP) represents another regenerative approach. Barbaro et al. (2024) reported a case of a young Rottweiler with a complex spiral tibial fracture treated with PRP and hydroxyapatite nanoparticles; significant improvements were observed ten days following treatment, with marked reduction in fracture gaps and increased callus density. López-Barbeta et al. (2019) conducted a prospective clinical study evaluating plasma rich in growth factors (a PRP derivative) in naturally occurring canine fractures, though further studies are needed to establish efficacy.

3.3. Antimicrobial Implant Coatings

Functionalizing orthopaedic implants with antibacterial coatings represents a promising strategy for preventing FRIs. López-Píriz et al. (2015) evaluated three antimicrobial glassy coatings in a dog model of peri-implantitis, demonstrating efficacy in preventing biofilm formation and reducing peri-implant bone loss. Ziąbka et al. (2020) developed innovative antibacterial composite hybrid coatings for titanium orthopaedic

Corresponding author: *Abouelhag H. A*
ha.elhag@nrc.sci.eg
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implants used in animals, incorporating silver nanoparticles; the hybrid layers effectively protected the implant surface against scratches and corrosion and eliminated bacteria, promoting bone healing.

3.4. Bisphosphonate-Antibiotic Conjugates

Bisphosphonate-antibiotic conjugates offer a "target-and-release" strategy for delivering high drug concentrations directly to infected bone. Sedghizadeh et al. (2017) designed a novel bone-targeting bisphosphonate-ciprofloxacin conjugate (BV600022) that demonstrated significantly enhanced therapeutic index versus ciprofloxacin alone in an animal model of osteomyelitis, reducing bacterial load by 99% with a single dose. Ren et al. (2023) developed bisphosphonate-conjugated sitafloxacin (BCS) and hydroxybisphosphonate-conjugate sitafloxacin (HBCS) for MRSA osteomyelitis in murine models; HBCS adjuvant with debridement and vancomycin therapy eradicated MRSA infection, with evidence of osseointegration and biofilm elimination.

3.5. Antimicrobial Photodynamic Therapy

Antimicrobial photodynamic therapy (aPDT) combines a photosensitizer and light activation to generate reactive oxygen species with broad antibacterial activity. Yin et al. (2022) explored aPDT using a novel photosensitizer (LD4) in a rabbit tibial osteomyelitis model caused by drug-resistant bacteria. The aPDT group achieved a >99.9% reduction in bacterial numbers, with significant bone repair observed histologically. While aPDT has been studied in veterinary dentistry for root canal disinfection, its application in orthopaedic FRIs remains experimental and warrants further investigation.

4. Future Directions and Research Priorities

Significant knowledge gaps remain. High-quality prospective clinical trials are needed to validate bacteriophage therapy, local antibiotic delivery systems, and regenerative biologics in client-owned dogs. Standardized diagnostic and treatment guidelines for FRIs should be developed (Johnson, 2020). Antimicrobial stewardship is essential to limit multidrug-resistant organisms. Novel approaches such as bisphosphonate-antibiotic conjugates (Sedghizadeh et al., 2017; Ren et al., 2023) and antimicrobial photodynamic therapy (Yin et al., 2022) offer promising directions for future research.

Conclusion

The treatment of fracture-related bone infections in dogs requires a multimodal approach: aggressive surgical debridement, appropriate antimicrobial therapy (guided by culture), and stable fracture fixation. Conventional strategies are challenged by biofilms and resistance. Emerging therapies—resorbable local antibiotic carriers (Cho et al., 2026; Bird et al., 2024; Fitzpatrick et al., 2005), bacteriophage therapy (Schweser et al., 2025), and antimicrobial implant coatings (López-Píriz et al., 2015; Ziąbka et al., 2020)—offer promising alternatives. Advanced surgical techniques (circular external fixation, bone transport, orthogonal plating with autograft) provide solutions for infected nonunions. Future progress depends on rigorous clinical research and translation of innovations from human orthopaedic trauma.

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Corresponding author: *Abouelhag H. A*
ha.elhag@nrc.sci.eg

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ha.elhag@nrc.sci.eg
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No original datasets were generated for this review article. All cited data and findings are available within the original research publications referenced in the manuscript, accessible via the provided Digital Object Identifiers (DOIs) or through respective journal platforms.

Corresponding author: *Abouelhag H. A*
ha.elhag@nrc.sci.eg