RESEARCH ARTICLE

Impact of Oral Glucosamine-Chondroitin-Methylsulfonylmethane Supplementation on Functional Recovery in Dogs with Diaphyseal Fractures

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Abstract

This study evaluated the effect of oral Glucosamine HCl, Chondroitin sulphate, and Methylsulfonylmethane (MSM) on fracture healing in dogs treated with minimally invasive external skeletal fixation (ESF). Twelve dogs with diaphyseal fractures of the radius-ulna or tibia-fibula were randomly assigned to two equal groups: Group I served as control, and Group II received oral Flexirun tablets (glucosamine, chondroitin, and MSM) for two months. Lameness and radiographic healing were assessed on the 7th, 15th, 30th, and 60th postoperative days. All dogs showed progressive improvement, but Group II demonstrated faster functional recovery and earlier callus formation, with significant differences in healing scores at day 30. By day 60, both groups achieved near-complete union, with excellent outcomes in most cases. The findings indicate that ESF provides effective fracture stabilization, while adjunctive glucosamine, chondroitin, and MSM accelerate recovery, reduce stiffness, and enhance limb function during the critical early and mid-recovery periods. Nutraceutical supplementation may therefore serve as a valuable adjunct in canine fracture management.

Key words: Chondroitin sulphate, Dogs, External skeletal fixation, Fracture healing, Glucosamine, Methylsulfonylmethane (MSM).

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Introduction

Fracture healing is a dynamic, multi-phase process encompassing inflammation, proliferation, and remodelling, where both mechanical stabilization and biological support are critical for optimal recovery (Meganck *et al*., 2013). In veterinary orthopaedics, external skeletal fixation (ESF) is commonly employed for diaphyseal fractures due to its minimally invasive nature, ability to maintain fracture alignment, and reduced risk of surgical complications compared to internal fixation (Johnson and DeCamp, 1999). Despite effective stabilization, enhancing bone healing and accelerating functional recovery remain ongoing challenges, particularly in promoting early callus formation and minimizing joint stiffness.

Glycosaminoglycans, including chondroitin sulphate, are integral to the extracellular matrix during the proliferative phase of bone repair, facilitating osteogenesis and matrix organization (Song *et al*., 2006; Jackson *et al*., 2006; Liang *et al*., 2010). Previous studies have shown that chondroitin sulphate can accelerate callus maturation and improve biomechanical strength without altering the ultimate bone quality (Karacal *et al*., 2005). Glucosamine, often combined with chondroitin and methylsulfonylmethane (MSM), supports joint health, reduces stiffness, and exerts anti-inflammatory effects, which collectively may improve ambulation and early functional recovery (Jerosch, 2011; Usha and Naidu, 2004; Kim *et al*., 2006). MSM further contributes to fracture repair by promoting osteoblast differentiation, enhancing extracellular matrix interactions, and modulating inflammatory mediators (Joung *et al*., 2012; Aljohani *et al*., 2019).

While the individual benefits of these nutraceuticals on bone and joint health are recognized, limited research exists on their combined effect on fracture healing in dogs treated with ESF. The present study was therefore undertaken to evaluate the influence of oral supplementation with glucosamine HCl, chondroitin sulphate, and MSM on

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radiographic healing, functional recovery, and clinical outcomes in dogs with diaphyseal fractures managed via minimally invasive external skeletal fixation. This investigation was aimed to determine whether adjunctive nutraceutical therapy can accelerate recovery and enhance overall treatment success in veterinary fracture management

Materials and Methods

The present study was carried out on clinical cases of fractures in dogs at the Department of Veterinary Clinical Complex, College of Veterinary Science, Garividi, Sri Venkateswara Veterinary University, Andhra Pradesh, India. Twelve dogs with diaphyseal fractures of the radius-ulna or tibia-fibula, irrespective of age or sex, were selected following thorough clinical, orthopaedic, neurological, and radiographic examinations. Animals with compound fractures or neuropathies were excluded. The dogs were randomly divided into two groups of six: Group I (n=6) was treated with closed reduction and type II external skeletal fixation (ESF), while Group II (n=6) received the same fixation along with oral Flexirun tablets (chondroitin sulphate, glucosamine HCl, and MSM) for two months.

Sedation for radiography (Fig. 1) was achieved using intramuscular Butorphanol, Acepromazine, and Glycopyrrolate. Anaesthesia for surgery consisted of premedication with the same drugs, induction with Propofol, and maintenance with Isoflurane. Fracture alignment was achieved under fluoroscopy, and percutaneous pins were placed in safe corridors (at least two in each fragment) and stabilized with connecting bars and clamps (Fig. 2).

Fig. 1: Skiagram showing complete proximal and mid diaphyseal comminuted fracture of left radius-ulna in group-I, and left tibia-fibula in group-II with irreducible wedges

Fig. 2: Skiagram showing anatomical reduction and alignment of fracture fragments during immediate postoperative period in group-I (left) & group-II (right).

Postoperative management included pin-site hygiene, topical antibiotics, capping of pin ends, bandaging, administration of Ceftriaxone and Meloxicam, and gradual return to activity. Fixators were removed after clinical and radiographic evidence of union. Follow-up evaluations were performed on the 7th, 15th, 30th, and 60th postoperative days, with lameness graded according to Cook *et al*. (1999) and final outcomes categorized as per Fox *et al*. (1995). Radiographs were used to assess fracture alignment, callus formation, cortical continuity, and healing progression, and healing was scored from 0-6 following Hayashi *et al*. (2008).

Results and Discussion

Clinical Evaluation (Lameness Scores)

All animals in both groups showed progressive improvement in lameness during the postoperative period (Table 1). Early weight bearing was noticed in group-II animals when compared to group-I. Within each group, the reduction in lameness scores across successive intervals was statistically significant, with animals improving from moderate to severe lameness immediately after surgery to negligible or no lameness by the end of the observation period. In group I, the improvement was gradual, with significant ($p<0.05$) differences noted between early and later postoperative intervals. In group II, recovery was faster, with most animals showing marked improvement as early as the 15th postoperative day, after which scores remained relatively stable (Table 1).

When groups were compared at corresponding intervals, group II consistently recorded lower mean lameness scores than group I, particularly during the early and mid-postoperative periods. However, these differences were not significant statistically. By the 60th post-operative day, both groups exhibited near-normal limb function with negligible lameness (Fig. 3, 4).

Table 1: Mean ± SE values of lameness scores and fracture healing score of two groups during different post-operative intervals

Criteria	Group	Days post-operative			
		7^{th} Day	15^{th} Day	30^{th} Day	60^{th} Day
Lameness score	Gr-I	3.83 ± 0.31^{C}	1.50 ± 0.22^{B}	0.67 ± 0.33^{A}	0.50 ± 0.22^{A}
	Gr-II	3.00 ± 0.37^{B}	1.00 ± 0.26^{A}	0.33 ± 0.21^{A}	0.33 ± 0.21^{A}
Fracture healing score	Gr-I	0.33 ± 0.21^{A}	2.0 ± 0.52^{B}	3.50 ± 0.22^{Ca}	5.83 ± 0.17^{D}
	Gr-II	0.50 ± 0.22^{A}	2.83 ± 0.41^{B}	4.00 ± 0.00^{Cb}	6.00 ± 0.00^{D}

Means bearing different superscripts (A,B) within a row for days and within a column (a,b) for a criterion differ significantly (p<0.05).

Fig. 3: Photograph showing clinical union in the operated limb in group-I on 60^{th} postoperative day.

Fig. 4: Photograph showing clinical union in the operated limb in group-II on 60^{th} postoperative day.

Radiographic Evaluation (Fracture Healing Scores)

Radiographic assessment revealed progressive callus formation, cortical continuity, and remodelling in all animals. Within each group, fracture healing scores improved significantly over successive intervals (Table 1), reflecting steady advancement of fracture repair. Between groups, healing scores were comparable at the early postoperative stage. From the 15^{th} day onwards, Group II demonstrated more advanced healing features compared to Group I, with the difference being particularly significant ($p<0.05$) on the 30^{th} postoperative day (Fig. 5). This finding indicates that Flexirun supplementation accelerated callus formation and cortical bridging. By the end of the observation period, both groups achieved near-complete radiographic union (Fig. 6), although Group II reached the stage of complete healing earlier.

Final Outcome

At the conclusion of the study, the final functional outcomes were graded as excellent in three cases of Group I and four cases of Group II, while the remaining cases in both groups were graded as good.

Fig. 5: Skiagram on 30^{th} postoperative day showing periosteal proliferation and osseous callus initiation in group-I (left), and exuberant osseous callus formation with appreciable radiolucent line in group-II (right)

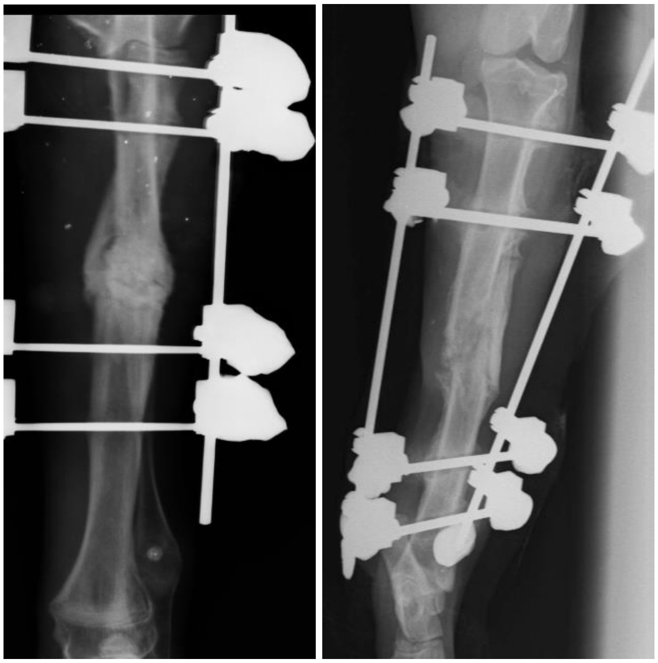

Fig. 6: Skiagram on 60th postoperative day showing complete radiographic union in group-I (left) and group-II (right).

Bone healing is a complex, multifactorial process comprising inflammatory, proliferative, and remodelling phases (Meganck *et al*., 2013). In the early proliferative phase, glycosaminoglycans such as heparan sulphate, dermatan sulphate, and chondroitin sulphate are crucial components of the callus (Song *et al*., 2006; Jackson *et al*., 2006). Chondroitin sulphate proteoglycans act as major contributors during this period, supporting matrix formation and osteogenic signalling (Liang *et al*., 2010). In agreement with this, Karacal *et al*. (2005) demonstrated that chondroitin sulphate accelerates bone healing. The present findings corroborated these observations, as group II animals supplemented with Flexirun showed earlier improvements in lameness and higher radiographic scores at day 30. Wibowo *et al*. (2021) confirmed that oral chondroitin sulphate produces comparable effects to local administration, with increased production of TGF-β, higher osteoblast numbers, and greater compressive strength of the fracture callus. These mechanisms likely explain the more advanced healing features observed in the supplemented group of the current study. Additionally, chondroitin sulphate plays a structural role in cartilage by enhancing resistance to stress (Baeurle *et al*., 2009), and together with glucosamine, it is widely used to support joint health and prevent osteoarthritis (Jerosch, 2011). Joint stiffness is a common complication of fracture management associated with prolonged fixation (Johnson and DeCamp, 1999). In this study, supplementation appeared to mitigate stiffness, improve comfort, and facilitate better ambulation. Glucosamine and chondroitin, along with hyaluronic acid, which lubricates joints and reduces friction (Beale, 2004; Alves *et al*., 2017) may have synergistically contributed to these favourable functional outcomes.

The role of MSM as part of the supplement is also noteworthy. MSM has long been combined with glucosamine and chondroitin for the management of arthritis (Usha and Naidu, 2004; Kim *et al*., 2006; Gregory *et al*., 2008; Lubis *et al*., 2017). Its contribution to fracture healing is linked to both anti-inflammatory and osteogenic properties. MSM inhibits inflammatory mediators such as IL-6 and TNF-α (Kim *et al*., 2009; Ahn *et al*., 2015), induces osteoblast differentiation via JAK2/STAT5b signaling (Joung *et al*., 2012), and enhances TG-2 activity and interactions with extracellular matrix proteins such as collagen type I and osteopontin (Aljohani *et al*., 2019). Furthermore, MSM increases the expression of osteogenic markers and mineralization in periodontal ligament stem cells and stem cells from exfoliated deciduous teeth (Joung *et al*., 2012; Aljohani *et al*., 2019; Ha and Choung, 2020). *In vivo* studies also demonstrate its potential in bone regeneration when combined with stem cells (Ha and Choung, 2020).

In the present study, while both groups achieved satisfactory union by day 60, the supplemented animals reached functional recovery and radiographic union earlier. The final outcomes were excellent in three cases of group I and four cases of group II, while the remaining cases were graded as good. This confirms that stable fixation is the main determinant of successful healing, but nutraceuticals can significantly accelerate the recovery process and improve limb function during the critical mid-recovery phase.

Conclusion

Overall, the findings of this study support the adjunctive use of glucosamine, chondroitin, and MSM in fracture management. These nutraceuticals not only promoted earlier radiographic healing but also reduced stiffness, enhanced comfort, and aided better ambulation of the operated limb. Thus, they may be recommended as part of postoperative care to enhance clinical outcomes in dogs with fractures.

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