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Review Article

Biological Osteosynthesis in Veterinary Practice: A Review

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Abstract

Biological osteosynthesis is not a technique but a concept of rational handling of traumatized bone fragments and surrounding tissues during fracture fixation so as to minimally expose the internal tissues including fracture haematoma to external environment. Fracture healing is a natural process and orthopaedic interventions should be attempted in a minimally invasive manner to preserve haematoma to facilitate the healing process. The decision regarding perfect anatomical reconstruction of fracture or functional stabilization should be made depending upon various factors. Exhaustive attempts to achieve exact anatomical reconstruction and traumatizing the vascular supply of already damaged tissue, may lead to pain and inflammation and thus delayed or non-union of a particular fracture. By applying strategies of biological osteosynthesis, fracture union may be enhanced and thus complications can be minimized. This review discusses the concept and scope of biological osteosynthesis in veterinary patients.

Keywords: Animals, Dynamic Fracture Fixation, Elastic Osteosynthesis, Minimally Invasive Surgery, Timing of Fracture Fixation

Introduction

Biological osteosynthesis is defined as a concept in fracture treatment to emphasise a sense of balance between anatomical reconstruction (Carpenter approach) and preservation of the biological potential for bone healing (Gardner's approach) (Palmer, 1999). The biological methods of fracture management limit the effect of rigid stability to optimise rapid healing by conserving the soft tissues structures adjacent to the fracture site. Biological osteosynthesis is the philosophy of treating comminuted fractures by bridging the fracture site without anatomic reconstruction of the fragments or judicious selection of basic orthopaedic techniques based on various factors like age, weight, breed and temperament of the animal for the management of simple or oblique / spiral diaphyseal fractures (Decamp *et al.,* 2016).

Fracture healing is a natural biological process and it can occur even without medical intervention; though, the healing may be inconsistent and unpredictable particularly in mature animals suffering from highly comminuted or unstable fractures. Besides, in many instances where aggressive orthopaedic interventions are not feasible such as in stray or wild animals (free ranging and captive conditions), fracture union occurs (Kumar, 2006); however, the long-term results of consequences of no or minimum orthopaedic intervention are lacking (Argyros and Roth, 2016). Without orthopaedic intervention, there is no additional disruption of the local vascular environment other than due to primary trauma that lead to fracture. The biological method of fracture repair is best suited in young healthy animals with great systemic "biological potential" for healing, particularly with inherently stable fractures such as incomplete or minimally displaced fractures.

Foundation of Biological Osteosynthesis

The disruption of the fracture hematoma and surrounding soft tissue structures delays bone healing as the hematoma has an inherent osteogenic potential (Schell *et al.*, 2017). Disturbing soft tissue at fracture site impedes formation of the extra-osseous blood supply necessary for callus formation and decreases the transfer of immune cells to the fracture site which further reduces resistance to infection leading to increased morbidity (Karnezis *et al.*, 1998). When preoperative radiographs suggest that anatomical reconstruction of comminuted diaphyseal fracture is questionable or extremely traumatic, the surgical priority can be adequate spatial alignment and stability with exhaustive efforts for the preservation of the blood supply to the fractured fragments (Palmer, 1999; Horstman *et al.,* 2004). This shift in surgical priorities is the foundation of biological osteosynthesis.

Advantages and Strategies

Biological osteosynthesis for the treatment of comminuted fractures has several advantages over traditional anatomic reconstruction. These include (1) shorter surgical times (2) lower infection rates, (3) decreased blood loss, (4) earlier return to function, (5) decreased rate of non-union, (6) reduced duration of hospitalization and faster fracture union (Palmer, 1999; Horstman *et al.*, 2004).

Specific strategies that may be employed to achieve biological osteosynthesis include (1) less traumatic surgical approaches, (Aron *et al.*, 1995) (2) rigid fracture fixation methods that minimize vascular insult to healing bone, (Frey and Olds, 1981) (3) less traumatic methods for application of orthopaedic implant, (Palmer, 1999) (4) cancellous bone grafting, (Joshi *et al.*, 2010) and (5) practicing progressive staged disassembly of the fixation system whenever possible (Schell *et al.,* 2017).

Methods of Biological Osteosynthesis

1. External Coaptation

External coaptation is one of the best and economical method to achieve biological osteosynthesis but case selection is critical (Harasen, 2012). Low to moderate body weight, young age, incomplete or minimally displaced diaphyseal or externally reducible fractures and docile behaviour of dogs are desirable (Harasen, 2012). As a general rule, a minimum of 50% contact between the fracture fragments is required for adequate fracture union to take place (Harasen, 2012). In non-athletic bovines, external coaptation using a combination of aluminium splint and fiberglass cast is the most economical and suitable method for the management of fractures of metacarpal / metatarsal (Yadav *et al.,* 2020) or to restore the near normal limb function in olecranon fractures of non-athletic bovines (Sangwan *et* *al.,* 2020). External coaptation had certain limitations, like in distal radius-ulna fractures particularly in small breed dogs, it may lead to non-union (Welch *et al.,* 1997; Harasen, 2012), its prolonged use may lead to fracture disease {joint stiffness, muscle atrophy, disuse osteopenia and soft tissue injury such as dermatitis (Harasen, 2012). Besides, external coaptation is unsuitable for articular and peri-articular fractures as such fractures require perfect anatomical reconstruction to prevent pain and osteoarthritis (Mecias and Mckee, 2003).

2. C-arm Guided Orthopaedic Procedure

C-arm or Fluoroscopy is mandatory for achieving closed reduction and to ensure correct placement of implant for fracture treatment (Kaur *et al.,* 2015; Umeshwori *et al.,* 2015). Closed alignment and stabilization is surgically less traumatic. Even fractures of the regions with less muscle mass (diaphyseal fractures of tibia and radius in young and small animals) or where fracture fragments can be palpated percutaneously, may be fixed with intramedullary pin without using fluoroscopy intensively. The same is not true for the fractures of the humerus or femur due to heavy envelope of muscles. Closed alignment and stabilization of fractures can be achieved with percutaneous pinning and plating, external skeletal fixators and interlocking nailing systems. Effective pre-operative traction relaxes muscles, thereby reduces the effective need for dissection to reduce the overriding fracture. Though, there are inadequate traction devices for veterinary patients but hanging a fractured limb from the paw using a thick cotton string and animal lying on the table in a ventro-dorsal position under general anaesthesia, may aid in relaxing muscles to facilitate closed reduction (Kaur *et al.,* 2015). Percutaneous plating in long bone fracture fixation minimizes soft tissue damage and preserves bone vascularity (Aggarwal *et al.,* 2020). Kim *et al.* (2012) recommended percutaneous pinning for the repair of non-displaced Salter-Harris Type 1 and 2 supracondylar femoral fractures in dogs and cats. Similarly, C-arm guided closed interlocking nailing technique for the repair of femoral fracture in dogs was assessed better based on early weight bearing and less pain score, as compared to open interlocking nailing technique (Manjunatha *et al.,* 2011).

In situations, where adequate fracture reduction and fixation cannot be accomplished with closed methods, one should choose an "open but do not touch" approach (Palmer, 1999). The objective of this approach is to achieve adequate spatial alignment of the two main bone fragments with minimal disruption of the hematoma in the region of fracture. This can be achieved by making two small skin incisions on either sides of fracture with blunt dissection of muscle bellies and positioning of the fixation system without directly exposing the fracture site to the exterior environment. Use of pointed instruments like Honnman’s bone elevator or mosquito artery forceps may facilitate fracture reduction through small incisions with limited exposure to the fracture site.

3. Intramedullary (IM) Implants

Steinmann IM pin, is one of the primitive and most commonly used method of biological osteosynthesis, as it requires minimum dissection of periosteum and surrounding tissues (Palmer, 1999). Intramedullary implants are placed in the neutral axis of bone and thus have superior ability to counteract bending forces than extramedullary implants such as bone plating (Weeler *et al.,* 2004; Raghunath *et al.,* 2012). But, this technique had certain inherent limitations also; poor rotational stability associated with round bodied implant and inadequate holding at the distal end (Kumar and Gahlot, 2013; Kaur *et al.,* 2015).

Modifications in the distal end of the pin such as screwed end (Shanz pin) has been reported to provide better stability by seating into the distal metaphyseal region and thus prevents complications of proximal pin migration (Kaur *et al.,* 2015; Kaur *et al.,* 2016; Gill *et al.,* 2018a; Priyanka *et al.,* 2019). However, the proximal end of implant being smooth, provides inadequate holding to prevent collapse of proximal fracture fragment while weight bearing (Kaur *et al.,* 2015), specifically in fractures with unstable configuration. Modifications such as fully threaded pin have been done to increase the stability of the intramedullary pin (Ozsoy, 2004; Altunatmaz *et al.,* 2012). Further investigations on the various configurations of the threaded intramedullary implants are required to develop a more stable, biological, cost effective and dynamic implant for veterinary patients.

4. Intramedullary Interlocking Nailing (IILN)

The IILN is another method of biological fracture fixation that revolutionized the canine orthopaedic surgery in India (Raghunath and Singh, 2002). One study by Horstman *et al.* (2004) recommended biological osteosynthesis over anatomic reconstruction for the repair of comminuted femoral fractures in dogs using interlocking nails. It was emphasised that in cases of comminuted fractures, it is sufficient to stabilize the main bone fragments using Interlocking nails, rather than anatomically reconstructing all minor bone chips. Biological osteosynthesis have advantage of reduced surgical and healing time without increasing complication rates. The IILN may be used in static or dynamic fashion depending upon the nature of fracture. Static IILN is most suitable for heavy weight animals with complex fractures (Raghunath and Singh, 2008; Raghunath *et al.,* 2012). Dynamic fracture fixation technique causes micro movements at the fracture site and thus, lead to early but bigger periosteal callus formation (Asif *et al.,* 2011). For dynamic IILN, generally distal or smaller bone fragment is locked using screws. However, there is lack of investigations comparing locking of proximal versus distal nail to achieve dynamic IILN fixation. In fractures with delayed or non-union, early rigid or static stability followed by allowing controlled axial microloading (dynamization) may be helpful (Vaughn *et al.,* 2016). Dynamization is staged removal of interlocking screws and it should begin 6 weeks after surgery or as soon as immature bridging callus is evident radiographically and on palpation (Aron *et al.,* 1995). However, this practice involves additional episode of general anaesthesia and surgical cost.

5. Biological Bone Plating System

Traditional method of bone plating (open reduction internal fixation) appears less biological as compared to intramedullary implants because it involves excessive dissection of soft tissues and striping of periosteum around the site of fracture, consequently disruption of the extraosseous blood supply leading to delayed or non-union and infection (Pazzi *et al.,* 2012); however, in certain situations such as fractures of flat bones or radius-ulna, the use of bone plates is mandatory (Welch *et al.,* 1997). The recent innovations in the design of bone plates from dynamic compression plate to limited contact dynamic compression plate have reduced the complications of 'stress-shielding' related complications such as cortical lysis, delayed union and re-fracture after plate removal (Unthoff *et al.,* 2006). Discovery of limited contact plate, helped in preserving the periosteal blood supply, by reducing the contact or pressure of plate on the bone. Further improvements in the plate design like locking plates with combi holes (DCP and locking) have increased the angular stability of the implant many folds. Commercial availability of titanium plates with modern designs (locking holes and limited contact) may be more biological, in terms of balancing stability and dynamic properties of the implant, in veterinary patients. Application of minimally invasive plate osteosynthesis and mini incisions bone plating technique have been reported for the repair of long bone fractures in dogs (Pazzi *et al.,* 2012, Aggarwal *et al.*, 2020).

6. External Skeletal Fixators (ESF)

The ESF can often be applied in a closed fashion with minimal additional disruption to the injured soft tissue envelope. As ESF does not disturb the site of fracture, so it is indicated for the stabilization of open fractures with massive soft tissue trauma (Cross and Swinontkowski, 2008). The stability of the assembly is dependent upon the type of ESF used. Patient positioning that involves hanging the affected limb to facilitate spatial alignment and stabilization of fractures of the radius-ulna and tibia-fibula is called the hanging limb position (Aron *et al.*, 1995). The ESF is particularly suited to highly comminuted diaphyseal fractures of the radius-ulna and tibia-fibula. Unlike medical practice, the care and maintenance of ESF assembly in veterinary patients is tedious and require animal and client compliance. Cited literature reports satisfactory results with a few complications (Aikawa *et al.,* 2019). In contrast, Singh (2019) stabilized open contaminated fractures of tibia and radius-ulna in dogs, using linear ESF and did not report encouraging results. Poor animal compliance, pin tract discharge, osteomyelitis, delayed union and non-union were major complications associated with linear ESF. As compared to other basic orthopaedic techniques, ESF is not a cost-effective fracture fixation method, so there is need to select cases considering various factors to utilize the biological potential of this technique.

7. Adjuvants to Enhance Fracture Healing

Autogenous cancellous bone grafts stimulate bone healing through the processes of osteogenesis, osteoinduction and osteoconduction (Joshi *et al.,* 2010). The proximal humerus, iliac crest and proximal tibia are most common graft harvest site in dogs. Care is exercised to prevent fracture at the graft collection site (Ferguson, 1996). The harvested graft should be gently placed in the thoroughly lavaged and stabilized fracture site without any interposition of dead space or necrotic tissue. In addition to autogenous cancellous bone, allogeneic cancellous bone can also be used and is commercially available in developed countries for veterinary use. Although, biologically inferior to autogenous bone, allografts are osteoinductive and osteoconductive. Fresh-frozen aseptically collected grafts are available in the physical form of cancellous chips or chips mixed with demineralized bone powder.

Mesenchymal stem cells (MSCs) have been a major research focus in regenerative medicine for the past several decades. Many experimental studies have yielded promising results but there is lack of adequate evidence for actual clinical use of stem cells in veterinary orthopedic patients. Following fracture, both cellular and molecular signals of bone injury are highly consistent with embryonic skeletal growth processes involving the mobilization and activation of MSCs for new bone formation (Bruder *et al.,* 1994). Kawate *et al.* (2006) used MSC/ β-tricalcium phosphate composite granules to treat steroid-induced osteonecrosis of the femoral head in humans after which osteonecrosis did not progress any further and early bone regeneration was observed.

8. Elastic Titanium Implants and Techniques

Presently, instead of stainless steel, orthopaedic implants made of titanium metal are getting popular for use as an elastic stable intramedullary implant for paediatric femoral fractures in human (Maher *et al.,* 2004; Bhasker, 2005). Titanium is reported to have lower modulus of elasticity and thus provides dynamic stability that facilitates early callus formation. Wider medullary canals and lower cortical strength makes immature growing patients more ideal for Titanium elastic nails (TENS). However, there is paucity of literature on the clinical use in TENS in veterinary practice. Titanium plates have been proved to be a safe and effective method for repairing maxillary, mandibular (Bilgili and Kurum, 2003) and long bone fractures (Syrcle and Cook, 2004) in small animals. Clinical use of single titanium rod as intramedullary implant have been reported for the management of diaphyseal long bones fractures in canines and ensured the accurate and safe stabilization with rapid return of limb activity (Jain *et al.,* 2018).

9. Timing of Fracture Fixation

Lastly, timing of definitive fracture fixation appears to be an important but largely ignored factor to achieve biological osteosynthesis. Though, definitive fracture stabilization is not considered a life threating emergency but timely decision for fracture fixation (preferably within 72 hours) may facilitate easy reduction with minimal requirement of dissection and thus, favouring concept of biological osteosynthesis. Delayed decision in fracture repair requires more invasive surgical dissection because of muscle contraction and early callus formation (Gill *et al.,* 2018b; Barnhart, 2020). Duration of supracondylar femoral fracture in dogs has been reported to have a direct impact on the haemato-biochmical alterations and possibility of fracture reduction with minimum dissection and bone nibbling and consequently, better postoperative functional outcome of adjacent joint (Gill *et al.,* 2018b).

Conclusion

Biological osteosynthesis, is a concept that emphasises the minimum handling of the traumatized bone fragments and surrounding tissues during fracture fixation and thus, enhancing fracture union and minimizing complications. A balance between fracture stability and soft tissue integrity is the prerequisite for early and successful outcome of fracture treatment. Exhaustive attempts to achieve anatomical reconstruction may be avoided which, may lead to delayed or non-unions. Various factors should be considered before deciding anatomical or functional reconstruction of fracture.

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Conflict of Interests

There is no conflict of interest.

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