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Elastic osteosynthesis in dogs – A Review

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Abstract
Over past few years, concept of biological osteosynthesis has been given a due weightage in long bone fracture fixation in canines as it involves maintaining the balance between carpenting and gardening approach to fracture fixation by veterinary orthopedic surgeon. Various techniques have been used lately which incorporate this concept, however, this article discusses elastic osteosynthesis in long bone fractures repaired using elastic nails put in dynamic intramedullary cross fashion especially in young dogs, where effort is made to preserve microenvironment around the site of fracture by preventing excessive soft tissue dissection and periosteal stripping in order to promote fracture healing as early as possible.

Keywords: Biological osteosynthesis, canine, dynamic intramedullary nailing, elastic nails

Introduction

Intramedullary pinning is one of the oldest and acceptable methods of internal fracture fixation. The technique is popular as the implant is cost effective, user friendly and more biological but it resists only bending forces acting across the site of fracture; thus, simple intramedullary pinning is frequently associated with certain postoperative complications such as migration of pin from site of insertion, nerve damage, breakage of pin etc. Among the several innovations in the orthopedic implant design and techniques, rigid fixation techniques such as bone plating, intramedullary interlocking nailing (Raghunath and Singh 2008) [14] and plate rod combination have gained more popularity for the repair of a variety of long bone fractures in small animals as these allow immediate weight bearing on the operate limb by equally distributing the load between implant and the reconstructed bony column. This also prevents premature implant failure as seen in intramedullary pinning (Palmer, 1999) [13]. However, such techniques necessitate exhaustive dissection of soft tissues and periosteum for placement of plate and drilling of holes to place screws along the fractured bone which defies principles of biological osteosynthesis by disrupting fracture hematoma and altering the vascular supply, therefore starving the bone from microenvironment necessary for fracture healing.

Concept of biological osteosynthesis recommends that fracture fixation should be attempted in a minimally invasive fashion and all attempts should be made to preserve the hematoma or soft tissue structural envelope surrounding the fracture site as thick muscles and soft tissues provide external support to the fracture fragments. A paradigm changes from the use of surgical techniques requiring excessive dissection to achieve anatomical fracture reduction to biological osteosynthesis by adequately balancing the carpenting and gardening approach to fracture fixation has occurred over the last two decades, where veterinary orthopedic surgeons have started incorporating the above concept of biological osteosynthesis in various techniques like external coaptation, C-arm guided orthopedic procedure, biological bone plating, intramedullary pinning, intramedullary interlocking nailing, and elastic nailing (Kumar *et al*., 2020) [9].

It has been reported that controlled micro-movements at the site of fracture (dynamic fracture fixation) is advantageous as it aids in early fracture union compared to static fracture fixation techniques such as using bone plates with compression. Titanium being a relatively elastic material than stainless steel; thus, it may be employed as an ideal dynamic material for orthopedic implants. Titanium implants are lighter in weight and allow controlled micro motion at the site of fracture that stimulates early callus formation by limiting stress shielding. Moreover, the lower modulus of elasticity of titanium compared with stainless steel makes titanium nails ideal for use in young human patients (Mahar *et al*., 2004) [11]. However, certain studies (Hayes & Richard, 2010; Goyal *et al*., 2014) [22, 23] have recommend the use of stainless steel elastic implant as it is stiffer and hence, can be used for relatively overweight patient and is also more economical than its titanium counterpart. Titanium implant is usually color coded.

In human and veterinary patients, biological osteosynthesis is the standard method for long bone fracture treatment, but a minimally invasive or 'open but do not touch' technique has also been used for long bone fracture repair, when closed reduction is impractical. During the last 2-3 decades several studies documented successful clinical applications of C-arm guided elastic nailing in human pediatric patients (Mahar *et al*., 2004) [11]. In contrast, limited applications are reported in the veterinary literature. This articles describes the feasibility, indications, procedure, and complications of elastic nailing in dogs and its role in helping the healing process with biological osteosynthesis.

What are Flexible / elastic nails?: Pin is usually sharp tipped that aids in its retention within the medullary canal while nail is usually blunt or chisel tipped and it is secured by screw or pin or by any other means. The small sized pins of stainless steel and titanium are called flexible/elastic nails (Fig. 1).

Due to broader medullary canal in the young humans (children) the elastic nails sized 1.5 to 5.0 mm are used (Salem *et al*., 2006) [15] but in the small animal orthopedics, flexible nails up to 2.5 mm are considered more suitable because of the much shorter bone length in dogs than humans; so smaller pin will be stiffer than longer pin of same diameter. The tip of the elastic nail is bent, usually angled at 30-40 degrees (Fig. 1), so as to facilitate insertion and orient their progression into the medullary canal and also to avoid penetrating the opposite cortex. However, longer bend of the tip might hinder the passage of nail inside the medullary cavity (Lascombes *et al*., 2006) [10].

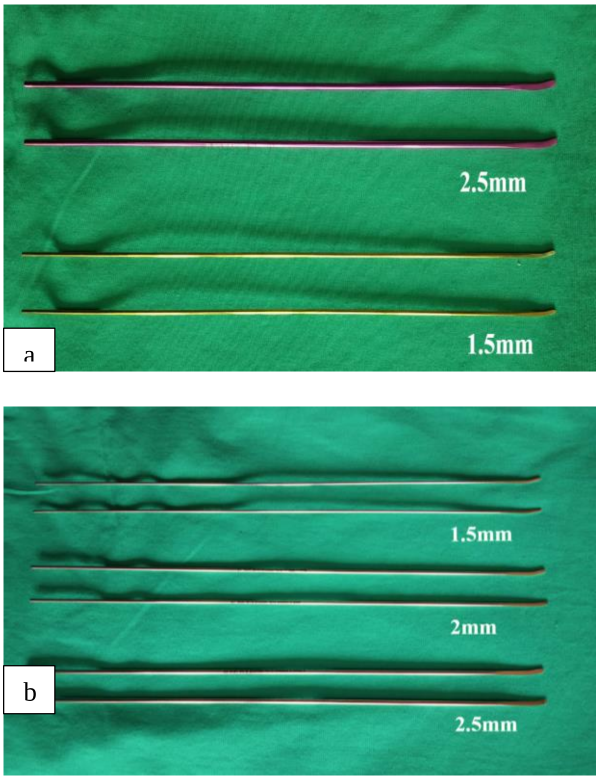

Fig. 1: (a) Titanium Elastic Nails; (b) Stainless steel Elastic Nails

What are other types of implants that have been used for dynamic intramedullary elastic nailing?

Elastic nails are being used as dynamic intramedullary implants in human pediatric orthopedic surgeries since 1977 and later Ender nails also made their way into the technique (Hunter, 2005) [5]. Ender nails differ from elastic nails as they have poor elasticity as compared to elastic nails. Also they have a flanged end, lacking in elastic nails, for the ease of removal of the implant. Mahajan *et al*., (2006) [24] have also suggested the use of Kirschner wire in dynamic intramedullary fashion but these implants could not get due popularity for dynamic fixation of fracture.

What makes elastic nails superior?

Single intramedullary pin (Simple or end threaded) in placed in neutral axis of long bone, thus the implant stability depends upon pin diameter and proper seating of the pin into the distal metaphyseal region. In contrast, the elastic pins are inserted from the either end of the bone, in a crossed intramedullary fashion (dynamic intramedullary cross), thus each pin creates three point fixation (six point fixation with two pins), that makes it superior over other internal fixation techniques as fixation at insertion and tip of the nail provide axial and rotational stability and apex of the curve provides dynamic stability (Mazda *et al*., 1997) [12]. Also, while loading elastic pinning creates a spring like effect along the axial direction at the site of fracture that stimulates callus formation. Juvenile dogs usually have broader medullary canals and weak cortex than adults, so one has to use smaller diameter intramedullary pins (upto 50% of the medullary canal diameter). Whereas using two elastic small diameter pins / nails provides better stability in young dogs as compared to single intramedullary pin (Sodhi *et al*., 2021a) [17].

As compared to other methods requiring rigid fixation, stability in cases of elastic nails is maintained not just by nails but also by the bone and the soft tissues surrounding it, hence making this technique extremely suitable for closed pediatric long bone fractures (Hunter, 2005) [5]. The nails provide internal elastic support, channeling forces and preventing excessive displacement by adjusting the bone fragments automatically. Elastic Stable Intramedullary Nailing allows for a certain amount of movement at the fracture site; thereby, ensuring optimum production of the external callus by reducing the shear and transforming it into compression and traction forces and also involves minimal periosteal stripping even when open reduction is necessary. The elastic nails result in early development of bridging callus which is about 2 times faster than rigid fracture fixation techniques. Overall, the use of elastic nails in dynamic fashion provides excellent biological environment for fracture healing and is also known to sustain greater load to failure as compared to other techniques (Sukhiani & Holmberg, 1997; Battle *et al*., 2006) [19, 1].

Indications: Flexible or elastic pins are indicated in young small to medium sized dogs, as it preserves the periosteum which is more thicker, biologically active in younger ones, hence an important support of blood supply as compared to adults (Hunter, 2005) [5]. Greater remodeling capacity in immature dogs as compared to adults also compensates for minor inaccuracies in the technique. It is used to stabilize a variety of diaphyseal fractures particularly transverse to short oblique that have relatively stable configuration. Long oblique or constructible comminuted fractures may require addition of cerclage wires. Immature dogs having broader medullary canal are truly beneficial with elastic nailing as compared to single large intramedullary pin. Also the metaphyseal region is dense in immature animals, leading to good purchase of the implant in this region. As small sized pins are used, so light weight dogs are more suitable candidates for the elastic nailing. Adult dogs are having heavy body weight with relatively narrow medullary canal, which makes them and humans less suitable for titanium elastic nails. Stainless steel flexible nails being mechanically stronger than titanium may offer advantage in heavy weighing dogs (Gupta *et al* 2023a; Gupta *et al* 2023b) [3, 4]. Recent cases with mild overriding or reducible fractures on external manipulation are ideal for C –Arm guided elastic nailing.

Elastic nailing can be performed in fractures of all bone types such as femur (Sodhi *et al* 2021a) [17], tibia, radius (Sodhi *et al* 2021b) [16] and humerus. Radial bone being flattened laterally and usually have small medullary canal, so this is most limiting factor for the use of elastic nails in radial fractures. However, it is possible to stabilize radial fractures using elastic nails in young dogs.

Selection of implant size for elastic nailing: Each elastic pin should occupy 30-40% of the narrowest medullary canal, (thus in total 60-80% by two pins). The use of an elastic pin of 1mm will provide adequate stability only in very light weighing young dogs, having the narrowest medullary canal of the fractured bone atleast 3.5-4.0 mm (as we have to count radiographic magnification as well). In my experience, one should use elastic nails of atleast 1.5 mm for which minimum medullary diameter should be 5-6 mm. So for broader medullary canals, nails of 2.0 and 2.5 are indicated. Considering the shorter length of the canine long bones as compared to human patients, the nails more than 2.5 mm would be very stiff.

Procedure of elastic nailing in dogs

This elastic nailing procedure can be performed with or without C-arm. C-arm facilitates closed reduction, hence, reducing trauma to surrounding soft tissue and reduces intra-operative complications. However, this increases the intra-operative radiative load experienced by patient and doctors.

In veterinary orthopedic practice, the C arm guided closed flexible pinning is only possible in early presented cases. Chronic cases may require open fracture reduction. C-arm guided closed nailing technique does not always lead to anatomical reduction, which depends upon the fracture configuration as well. Transverse to short oblique mid diaphyseal fractures are best suited for C-arm guided closed pinning (Kaur *et al* 2015) [6]. The less perfect anatomic reduction together with the low torsional nail stability, can lead to a higher rate of malalignment or limb length discrepancies.

This procedure of titanium / stainless steel elastic nailing in dogs has been described recently (Sodhi *et al*., 2021a; Sodhi *et al*., 2021b; Gupta *et al*., 2023b) [17, 16, 4] requires 2 titanium / stainless steel elastic nails placed in a dynamic intramedullary cross fashion. The size of the implant is chosen to ensure that each implant covers at least 30-40% of the narrowest medullary cavity diameter of the affected bone, which is measured using built-in measuring software in computerized radiography system. The 2 implants should be of equal sizes so as to prevent asymmetrical forces at fracture site. The elastic nail has a pre-bent tip which facilitates its sliding down the inner surface of opposite cortex, otherwise straight nail might pierce the opposite cortex. The other end of the nail which is blunt should also be bent in same direction and to same extent as the pre-bent tip with an orthopedic plier, so as to identify the direction of nail inside the medullary cavity in absence of fluoroscopy. Other reports describe use of single elastic nail for the management of various long bone fracture fixation (Prabhukumar *et al*., 2020; Bishnoi *et al*., 2021; Kumar *et al*., 2022) [21, 2, 8]; however, in the author's opinion, two elastic nails should be preferred. Use of single nail has been reported adequate for the stabilization of long bone fracture fixation in children because post operatively such patients can be bed rest which is not practical in animals.

After the fracture site has been prepared for surgery, it is adequately draped by scrubbed, gowned and gloved surgeon. The elastic nails chosen are pre-curved to an extent so that the depth of the curvature is three times the narrowest medullary cavity diameter and the maximum curve should approximate the level of fracture site so as to achieve 3 point fixation with each elastic nail, i.e., at penetration site and tip of nail which confers axial and rotational stability and one at the apex of the curve, just proximal to fracture site which confers dynamic stability by providing constant transverse distractive shear as discussed previously. The idea of curving the nail is to prevent its straightening or further bending and hence to resist implant deformation.

C-arm is positioned accordingly. The nail insertion site can be marked on the limb with the help of sterile marker. The insertion sites are different for different bones, which are as follows:-

- **Femur:** Just caudal to epicondyles on both lateral and medial side of distal femoral condyles (Sodhi *et al*., 2021b; Gupta *et al*., 2023b) [16, 4]
- **Radius:** Medial and dorsolateral aspect of distal radial fragment. Additionally single intramedullary pin may be inserted using retrograde technique into the ulnar bone to provide additional stability Sodhi *et al*., 2021a [17].
- **Tibia:** On either side of tibial tuberosity, i.e., at a mid-point between anterior tibial tuberosity and fibular head on lateral side and at a mid-point between anterior tibial tuberosity and posterior part of tibia medially (Srinivas Reddy *et al*., 2021; Kumar *et al*., 2022) [18,8].
- **Humerus:** 1 or 2 entry points on lateral condyle, just above the epicondyle.

Ideally, elastic nails should be inserted from metaphysis of all the bones, to prevent physeal damage and hence bone shortening. But, canine pediatric bones are smaller than human pediatric bones, leaving very small distal fragments in canines, thus, affecting the purchase of distal fragment if implant is placed from the metaphysis.

Once the insertion site is identified a stab incision is made over it and soft tissue underneath is cleared with the help of artery forceps. A pilot hole with the help of small awl or a Steinmann pin of the same size as elastic nails is created under C-arm guidance at an angle of 20-30 degrees to the longitudinal axis of the bone. The, elastic nails are placed inside the pilot hole and are simultaneously advanced inside the medullary cavity up to fracture site under fluoroscopic guidance. Once both the nails reach the site of fracture, fracture is reduced by longitudinal traction under C arm guidance. In cases where closed reduction is not possible, a 2-3 mm K wire or sharp elastic nail can be inserted to the fracture gap from a dorsal stab incision which will act as a lever arm and distal fragment can be raised up and can be slid forward onto the proximal end to achieve satisfactory reduction (Varga *et al*., 2017) [20] under fluoroscopic guidance. Once the satisfactory fracture reduction is achieved, the nails are hammered into the medullary cavity simultaneously under C-arm guidance, especially while placing pre-bend nails, to provide equal distractive forces at all times and hence, preventing mal-alignment at fracture site. In case, where nails are not pre-bent, after the nails are advanced to a sufficient length inside the medullary cavity, the ends are curved using the orthopedic plier to confer the 3-point stability to each elastic nail. The construct should be in a symmetrical alignment face to face with the maximum curvature of the nails at the level of the fracture. The excess of the nail is cut close to the cortex of the condyle to prevent irritation of soft tissue by cut ends of nails. Skin incision on either side is closed routinely. In conditions where fluoroscopy is not available, open reduction is warranted and the elastic nails of same length are used to measure the extent of nail inside the medullary cavity from outside. During the entire procedure, care must be taken to not significantly disrupt the vascular supply from periosteum and extraosseus vascular supply and hence the microenvironment in order to aid in the healing process.

Instrumentation: Apart from general orthopedic pack, certain specific instruments are required to perform flexible pinning. These include

- Elastic nails (titanium or stainless steel) of various sizes
- Micro Awl: to create pilot holes in the metaphyseal region of the bone. Alternatively drill bit or suitable sized Steinman pin / K-wire may be used.
- Chuck with extension rod and hammer: to facilitate pins insertion into the medullary canal.
- Orthopedic Plier: To bent titanium nails and nail removal following fracture union.
- Wire cutter: to cut the extra length of the pins

Complications of Elastic nailing: Like any other technique, elastic nailing technique is also associated with certain complications that include implant migration, irritation of soft tissues at the site of implant insertion and hence leading to joint stiffness, delayed union, superficial infection at insertion site when implant is placed percutaneously, limb length discrepancy (more in cases with spiral, comminuted fractures) and angulation at the site of fracture.

Removal of the implant: The implant is not routinely removed and its removal is warranted only in cases of implant migration, excessive soft irritation leading to joint stiffness or in cases of any other implant related complications.

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