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REVIEW ARTICLE

Stabilization of Fractures with the Use of Veterinary Interlocking Nails

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ABSTRACT

Interlocking nails (ILN) are effective tools for the fixation of long bone fractures, including humeral, femoral and tibial fractures. An interlocking nails are a steel rods which are placed in medullary canal of fractured bone. They have transverse openings which are use to put inside a transcortical screws. Those screws block the nail relative to the main bone fragments. Interlocking nails counteract all forces at the fractured site, thus they are an alternative to bone plates. Simultaneously, the intramedullary nail is placed in a natural position relative to the bone's biomechanical axis and neutralizing bending forces across bone fragments. Unlike bone plates that are eccentrically positioned, the nail has an intramedullary position which makes it much more resistant to compressive, torsional and bending force. This technique requires a relatively low surgical approach to compare with plate osteosynthesis. Most importantly, interlocking nails support biological osteosynthesis and fracture management with minimal surgical intervention. The first application in veterinary medicine of the interlocking nail was at the late 1980s. Since this moment, the technique still evolves providing the next generations of interlocking nails. At these days we have several generations of it. This paper discusses the use of interlocking nails in fracture stabilization in veterinary practice and overviews the development of nail implants and their applications. The advantages of the analyzed technique and the associated complications are discussed.

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INTRODUCTION

Osteosynthesis by interlocking nails (ILN) is a new and attractive method for treating long bone fractures in animals, and it offers an alternative to plate osteosynthesis (Dejardin *et al.,* 2006). Unlike bone plates, interlocking nails fully support the concept of biological osteosynthesis which argues that soft tissue protection and the restoration of blood supply to bone fragments are more important than anatomical reconstruction in the treatment of long bone shaft fractures (Aron *et al.,* 1995; Johnson *et al.*, 1996; Johnson *et al.*, 1998; Karnezis *et al.,* 1998; Claes *et al.,* 1999; Field and Tornkvist, 2001; Horstman *et al.,* 2004). Interlocking nails have been used in veterinary medicine since the late 1980s (Johnson and Huckstep, 1986). The new method did not gain widespread popularity in the treatment of bone fractures in animals because the insertion of locking screws into the nail's transverse openings required fluoroscopic control (Moses *et al.,* 2002; Wheeler *et al.,* 2004a). The first clinical treatment of a tibial shaft fracture in a dog with the involvement of an interlocking nail was described by Muir *et al.* (1993).

Structure of an interlocking nail: An interlocking nail is an intramedullary steel rod with transverse openings at both ends. Locking screws are inserted into the openings; they are anchored in the cis- and trans-cortex to block the nail relative to the main bone fragments (Georgiadis *et al.,* 1990; Russel *et al.,* 1991; Brumback, 1996; Dueland *et al.,* 1996; Moses *et al.,* 2002; Moores, 2008; Lu *et al.,* 2009). In most nails, one end features a trocar point or a blunt end, and the other end has a threaded center. The threaded end facilitates the assembly of an alignment guide which supports the insertion of locking screws into the nail's transverse openings without fluoroscopic control. Locking screws may be standard Arbeitsgemein-schaft für Osteosynthese- fragen (AO)/Association for the Study of Internal Fixation (ASIF) screws (Dueland *et al.,* 1999), bolts (Lansdowne *et al.,* 2007) or elongated blocking screws interconnected with an external fixator (Nanai and Basinger, 2005; Goett *et al.,* 2007).

Biomechanics: Interlocking nails allow rigid fracture stabilization and present biomechanical advantages when compared to other immobilization techniques (Romano *et al.,* 2008). ILN counteract all forces at the fractured site (Patil *et al.,* 2008). The intramedullary nail is placed in a natural position relative to the bone's biomechanical axis, thus neutralizing bending forces across bone fragments. Transverse locking screws anchor the nail relative to the main bone fragments to resist compressive and rotational force (Muir *et al.,* 1993; Trostle *et al.,* 1995; Brumback, 1996). Unlike bone plates that are eccentrically positioned, the nail has an intramedullary position which makes it much more resistant to compressive, torsional and bending force (Wheeler *et al.,* 2004a). The results of research into the biomechanical properties of interlocking nails and DCP plates have demonstrated that owing to their structural properties, interlocking nails are characterized by a greater moment of inertia than bone plates; therefore, they are more resistant to bending force (Muir *et al.,* 1995; Bernarde *et al.,* 2001). Interlocking nails are also less susceptible to compression (Bernarde *et al.,* 2001). The spring-back effect of interlocking nails delivers an additional advantage. The nail-bone connection is somewhat flexible. The application of torsional force causes low deflection, and the connection easily returns to its original position (Kyle *et al.,* 1991; Dueland *et al.,* 1996).

In fracture sites marked by a scarcity of fibrocartilage callus or during prolonged bone healing, the interlocking nail technique supports dynamization (Hajek *et al.,* 1993). A dynamic mode of fracture fixation involves the removal of nail locking screws from one of the bone fragments (Durall and Diaz, 1996; Dueland *et al.,* 1999). The above procedure increases compressive forces at the fracture site (Georgiadis *et al.,* 1990) which stimulate bone healing.

Development of the ILN technique: Since its invention, the structure of the interlocking nail has undergone a series of key modifications involving changes in diameter, the applied material, the number and distribution of transverse openings. Some nails were designed for insertion into the medullary space from the proximal end towards the distal bone end (antegrade), while a reverse technique was applied in other models (retrograde). Today, several interlocking nail systems are available for veterinary applications. They have been developed in Australia (Johnson and Huckstep, 1986), Spain (Durall *et al.,* 1993), France (Duhautois, 1995; Duhautois, 2003) and the United States (Dueland *et al.,* 1999).

The Dueland Interlocking Nail System (Innovative Animal Products Inc., Rochester, MN, US) was the first technique engineered exclusively for veterinary applications. In 1989, Dueland (University of Wisconsin) began investigations to apply a human fracture modality to veterinary orthopedics, and the first report on a veterinary interlocking nail system was published in 1993 (Duhautois, 2003). The system was introduced for commercial use in 1994 (Roush and McLaughlin, 1999). It relied on an alignment guide fixed to the interlocking nail which facilitated the correct orientation of locking screws relative to transverse openings. The above solution eliminated the need for fluoroscopic control during nail insertion (McLaughlin, 1999).

The first three generations of interlocking nails were applied in the treatment of long bone fractures (Durall and Diaz, 1996; Dueland *et al.,* 1999; Horstman *et al.,* 2004). First-generation nails were available in three different lengths and four diameters (4, 6, 8, 10 mm). One end had a trocar point, and the other end was negatively threaded for fixing the alignment guide for the correct positioning of locking screws relative to transverse openings. The nail had three transverse openings for inserting locking screws, one in the proximal section, and two in the distal sections of the nail. First-generation nails were inserted from the proximal end towards the distal end of the bone. A retrograde fixing method was used with the application of a screw-in trocar end. The nail was locked with standard ASIF/AO cortex screws with the diameter of 2 mm for 4 mm nails, 3.5 mm for 6 and 8 mm nails, and 4.5 mm for 10 mm nails (Duhautois, 2003).

The method of fixing the alignment guide was modified in second-general nails. A threaded nail end was replaced with a grooved fixing system for easier and safer guide assembly (Dueland *et al.,* 1999; Duhautois, 2003). Second-generation nails had varied length (92 – 199 mm) and three standard diameters (4, 6, 8 mm). To minimize the risk of mal-positioning locking screws, the first-generation guide was replaced with two exchangeable guides, one designed for use with 4 mm nails, and the other – for 6 and 8 mm nails (Duhautois, 1995; Duhautois, 2003).

The key modification in third-generation interlocking nails consisted in the use of new locking screws with a larger diameter than standard AO/ASIF cortex screws. This change was dictated by observations suggesting that standard screws were often damaged by the applied force (Duhautois, 1995). The new screws designed for 4 mm nails had the diameter of 2 mm, and they were available in six different lengths (10, 12, 14, 16, 18, 20 mm). The screws intended for 6 and 8 mm nails had the diameter of 3.5 mm, and they came in nine different lengths (16, 18, 20, 22, 24, 26, 28, 30, 32 mm). Interlocking nails were available in the following formats: diameter of 4 mm with the length of 92, 100, 109, 119, 130, 142 mm; diameter of 6 mm with the length of 139, 149, 160, 172, 185 mm; and diameter of 8 mm with the length of 160, 172, 185, 199 mm (Duhautois, 2003).

To treat long bone fractures in dogs, Dueland *et al.* (1999) created three different generations interlocking nails of his own idea. First-generation nails were rods with the length of 300 mm and diameter of 6 mm and 8 mm. They had numerous transverse openings that were distributed evenly along the nail at 22 mm intervals with trocar points at both ends. The nails were suitable for both antegrade and retrograde fixation. The nail was inserted into the medullary space, and an alignment guide was fixed to the proximal end of the nail protruding above the bone surface. The guide was additionally screwed to the first transverse opening. The guide had openings which ensured the correct positioning of locking screws relative to transverse openings. The guide arm was separated by a distance of 60 mm from the nail. The nail was locked, the guide was removed and the nail was cut to length. Locking screws designed for 6 mm nails had the diameter of 3.5 mm, and the screws intended for 8 mm nails had the diameter of 4.5 mm. The distribution and the number of locking screws were determined by bone length and the type and configuration of the fracture. Second- and third-generation nails involved modifications based on clinical experience gained during fracture treatment with the use of first-generation nails. Second-generation nails were available in two different lengths (140 and 230 mm), but their diameter was not modified. The number of transverse openings was reduced to five or seven. The trocar-shaped end was replaced with a groove for guide assembly. First- and second-generation nails were modified to eliminate the number of redundant transverse openings, to prevent the nail from sliding out of the bone and damaging the sciatic nerve, and to prevent the drilling of incorrectly positioned openings to insert locking screws. Third-generation nails came in five different lengths (140, 160, 185, 205, 230 mm). The number of transverse openings was reduced to two on each end of the nail. The element for fixing the guide to the nail was manufactured in two different lengths (80 and 120 mm). The longer variant was applied to stabilize the tibia and prevent the guide from interfering with the patella or the femoral condyle (Dueland *et al.,* 1999).

Fourth-generation nails were developed to stabilize proximal and distal metaphyseal fractures. They feature only two transverse openings, one at each end of the nail. Owing to this solution, an empty opening is no longer left in the fracture site (Reems *et al.,* 2006). Attempts were also made to heal femoral fractions in dogs with the involvement of plastic interlocking nails. Nails were blocked with metal screws, but this solution failed to provide the required degree of rigidity at the fracture site (Church and Schrader, 1990).

Continued research efforts are made to improve the interlocking nail system by optimizing the nail structure for greater fracture stabilization and perfecting the nail locking system. Recently proposed solutions involve an hourglass-shaped nail that reduces torsional force at the fracture site (Dejardin *et al.,* 2006), locking screws that provide for tighter contact with the nail and better anchoring in the cortical bone (Lansdowne *et al.,* 2007; Ting *et al*., 2009; Dejardin *et al.*, 2011), as well as nails used in combination with type I external fixators for greater structural reinforcement (Basinger and Suber, 2004; Durall *et al.,* 2004; Goett *et al.,* 2007; Wendelburg *et al.,* 2011).

Indications: The osteosynthesis technique involving interlocking nails is used in the fixation of both simple and comminuted fractures of the humerus (De Marval *et al.,* 2011), femur (Bellon and Mulon, 2011) and tibia (Lu *et al.,* 2009). ILN may represent a reliable fracture stabilization method for diaphyseal fractures as well as fractures involving the metaphyseal regions (Ting *et al.,* 2009). In the ILN method, the required length of the proximal and distal sections of the fractured bone has to be preserved for anchoring transverse locking screws. Although the majority of treated cases involve closed fractures, interlocking nails can also be used in the fixation of open and infected fractures (Dueland *et al.,* 1999; Moses *et al.,* 2002).

Advantages of the ILN method: Interlocking nail fixation supports bone stabilization without or with minimal surgical intervention (Dueland *et al.,* 1999; Bernarde *et al*., 2001; Wheeler *et al.,* 2004b; Weninger *et al.,* 2009). The discussed method reduces blood loss during the procedure, it speeds up healing time and the recovery of limb function and it minimizes the risk of complications, such as infections or incomplete bone union (Horstman *et al.,* 2004). Fracture repair involving intramedullary nails is a shorter procedure than plate osteosynthesis (Crates and Whittle, 1998; Lin *et al.*, 1999; Sarmiento *et al.,* 2002; Scheerlinck and Handelberg, 2002; Im and Tae, 2005). As a biological osteosynthesis method, the ILN technique minimizes disturbance to blood supply in the fracture site (Dueland *et al*., 1999).

Complications in ILN osteosynthesis: The most frequent complications reported in interlocking nail osteosynthesis in animals are: nail damage (Duhautois, 2003; Dueland *et al.,* 1999; Basinger and Suber, 2002; Horstman and Beale, 2002; Lorinson and Grösslinger, 2002; Horstman *et al.,* 2004), loosening of bone implants (Horstman *et al.,* 2004), damage to locking screws (Durall and Diaz, 1996; Dueland *et al.,* 1999; Larin *et al.,* 2001; Horstman and Beale, 2002; Lorinson and Grösslinger, 2002; Moses *et al.,* 2002; Langley-Hobbs and Friend, 2002; Suber *et al.,* 2002; Duhautois, 2003; Durall *et al.,* 2003), delayed bone union (Klein *et al.,* 2004), absence of bone union (Larin *et al.,* 2001; Duhautois, 2003) and osteomyelitis (Moses *et al.,* 2002). Osteolysis in cancellous bone around the distal end of the ILN known as a "windshield-wiper effect" has also been reported (Durall *et al.,* 2003; Rodrigues *et al.,* 2009).

In human medicine, the ILN technique also involves the potential risk of damage to nerves, arteries & muscles in the area of locking screw fixation (Albriton *et al.,* 2003; Bono *et al.,* 2000; Evans *et al.,* 1993; Lin and Hou, 1999; Lögters *et al.,* 2008, Prince *et al.,* 2004; Riemer and D'Ambrosia, 1992; Rowles and McGrory, 2001).

According to Dueland *et al.* (1999), the main causes of nail breakage in osteosynthesis include material fatigue, the use of nails with insufficient diameter and positioning the nail in such a way that the transverse opening overlaps on the fracture line or is situated in its immediate vicinity. Malpositioning the nail in the medullary space could damage the nail's threaded proximal end, thus preventing the fixation of the alignment guide and the stabilizer (Duhautois, 2003). Damage to locking screws is regarded as a less serious complication because it generally does not disrupt the bone healing process (Moses *et al.*, 2002; Durall *et al.*, 2004).

Conclusions

The fractures care by the use of intramedullary interlocking nails is still increasing in popularity in veterinary medicine. Biomechanical properties of this method have many advantageous compared with other fixation modalities. Taking into consideration the constant development of veterinary interlocking nails, one should suppose, that similarly how it took place in the human medicine, this method of osteosynthesis will became a technique by choice in treating of long bone fractures at animals.

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