Original Article

Interlocking nail stabilization technique for long bone fractures in calves

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Abstract

The aim of this study was to report the clinical and radiographic outcome from using an interlocking nail (ILN) technique for the stabilization of long bone fractures in 15 calves. Forty-eight calves with fractures were presented to the large animal hospital. Fifteen calves of different breeds, age, sex and weight with front or hind limb fractures were considered suitable for ILN application. These included proximal or distal diaphyseal transverse and oblique fractures of the humerus, radius, femur and tibia. The third generation of six, eight, nine and 10mm diameter interlocking nails were used in this study. Interlocking pins were used for 15 calves, whose fractures included seven femur (46.6%), four tibia (26.6%), two humerus (13.3%) and two radius (13.3%). Ten out of the 15 calves (66.6%) recovered well without any problems in the post-operative period. In five cases (33.3%), there were complications due to various causes such as infection or wound breakdown or they were slaughtered in the post-operative period. The success rate was linked to the post-operative care conditions, so despite the short period of the operation and good fixation, any success rate was often reduced by inadequate management in the post-operative period. This study showed that fractures occur particularly during birth, due to inappropriate obstetric assistance, potentially causing severe economic loss for the cattle industry. The interlocking nail stabilization technique could have widespread application for calf orthopedics.

Keywords: Calf, Interlocking Nail Stabilization Technique, long bone fracture

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Introduction

Femoral and tibial fractures are the second and third most common bone fractures in newborn calves after metacarpal and metatarsal fractures (Guy, 1991; Gülaydın and Sarıerler, 2018; Feist *et al*., 2019). Excessive and unconscious use of force during aided birth has been reported as the main cause (Feist *et al*., 2019). It has been also reported that tibial fractures observed in calves are caused by traction force applied at birth in the caudal position or trauma experienced in the days following birth (Martens, 1998). Tibial fractures reported account for 15 to 41% of long bone fractures in cattle (Nuss *et al*., 2011).

Decisions on fracture treatment in calves are based on factors such as treatment costs, success rate of treatment, economic and genetic potential of the animal and localization and type of fracture (Piórek *et al*., 2012). Conservative treatments such as splints, plaster and thermoplastic casting applied to closed fractures in metacarpal and metatarsal bones are generally successful (Anderson, 2004; Spiess, 2004). Intramedullary nails are frequently used for the treatment of long bone fractures because of the advantages of low cost, easy application and removal, minimal damage to the epiphyseal plate and shorter operation time than for plating (Nuss *et al*., 2011). The disadvantages include weak rotational stabilization, movement in the fracture line and negative effects on endosteal callus formation (Has *et al*., 1995; Chapmon, 1996; Dueland *et al*., 1996). In order to eliminate the disadvantages of intramedullary nails, interlocking nails (ILN) have emerged as a modification of the Kuntscher pin (Dueland, 1998; Spiess, 2004; Marturello *et al*., 2019). The interlocking nail is an alternative technique for treating long bone fractures in animals and presents a useful alternative to plating (Moses *et al*., 2002; Spiess, 2004, Fauron *et al*., 2018, Paolucci *et al*., 2018). In contrast to plating, ILN entirely supports the concept of biological osteosynthesis, which suggests that reduced soft tissue damage and renewal of blood flow in bone fragments are more important than anatomical reconstruction in the treatment of long bone fractures. One of the major disadvantages of ILN is the need for fluoroscopic control due to the difficulties with the transverse insertion of screws (Arican *et al*., 2017) but this has been minimized recently in modifications made to the system (Arican *et al*., 2017). The ILN technique allows for rigid fracture stabilization compared to other immobilization techniques, while offering several biomechanical advantages with the ability to withstand all forces in the fracture site (Moses *et al*., 2002). It is increasingly used in small animal surgery and due to the advantages mentioned above, it has become important to investigate the application and clinical results for the use of ILN in the treatment of long bone fractures in calves.

The aim of the study was to report the clinical and radiographic outcomes after use of ILN for the stabilization of long bone fractures in calves.

Materials and Methods

Animals: Forty-eight calves with fractures were presented to the large animal hospital. Fifteen calves of different breeds, age, sex and weight with front or hind limb fractures were considered suitable for ILN application. ILNs were used for fractures in which the bone could not be reconstructed, such as both highly comminuted or one segmented fractures . This fixation method was typically selected in very rigid repairs that could counteract all forces and were entirely load bearing until bone healing had progressed to callus formation, even when limited bone length was available proximally or distally, as their corresponding bolts do not require much available bone length for placement.

Clinical examination of each case confirmed fracture location, infection findings were recorded and cranio-caudal and medio-lateral radiographs of the fracture were obtained by radiological examination. In this study, proximal or distal diaphyseal transversal, oblique fractures of the humerus, radius (Fig.1), femur (Fig.2) and tibia were found and ILN was recommended for all long bone fractures. Information about post-operative period care conditions and complications that might occur was given to the owners of the15 cases who had operations.

Figure 1 Medio-lateral radiographic views of the right ulna and radius in case 14 (Holstein 1-day old) showing transversal diaphyseal fracture.

Figure 2 Medio-lateral radiographic views of the left femur in case 5(Simmental 5-day old) showing mid-diaphyseal transversal fracture.

In the preoperative period for the 15 cases that underwent ILN implant sizes were measured on the radiographs and selected based on the different weight of the calves and the length and diameter of the broken bone.

Classification of Fractures: Fractures were classified by their location as to whether they were comminuted or non-comminuted, transverse, longitudinal, spiral and oblique according to a single fracture line (Table 1).

Table 1 Post-operative evaluations of the calves with fracture.

Calf No.	Breed and Age	Gender	Diagnosis	Post-Operative Evaluation
1	Holstein 2-day old	Male	Distal diaphyseal oblique fracture of left radius and ulna	(4), the suture site was open after 7 days post-op.
2	Holstein 1-day old	Male	Left femur, moderate diaphyseal oblique fracture	(2), No walking problem and good general condition
3	Holstein 7-day old	Male	Distal diaphyseal, oblique fracture of right humerus and metacarpal fracture	(2), No walking problem and good general condition
4	Simmental 5-days old	Male	Mid-diaphyseal transversal fracture of left femur	(2), No walking problem and good general condition
5	Brown Swiss 3-days old	Male	Distal diaphyseal oblique fracture of the left femur	(2), no walking problem and general condition is good
6	Holstein 7-day old	Male	Oblique fragmented fracture on the left tibia	(2), no walking problem and general condition is good
7	Brown Swiss 3-days old	Male	Distal diaphyseal oblique fracture of the left humerus	(4), Infection-related death at the end of post-operative 5th day.
8	Holstein 1-day old	Male	Diaphyseal oblique fracture distal to right femur	(4), Infection-related death at the end of post-operative 2nd day.
9	Holstein 15-day old	Female	Mid diaphyseal spiral fracture on the left femur.	(4), In the post-operative period, the extremity was not used and died one month later.
10	Simental 2-day old	Male	Mid diaphyseal oblique fracture on right tibia	(2), no walking problem and general condition is good.
11	Holstein 1-month old	Male	Mid diaphyseal oblique fracture on right tibia	(2), In the post-operative period, operation site was infected. no walking problem and general condition is good.
12	Holstein 15-days old	Male	Distal diaphyseal oblique fracture on the right femur	(4), Infection-related death at the end of post-op.
13	Holstein 7-days old	Female	Mid diaphyseal spiral fracture on the right femur.	(2), no walking problem and general condition is good.
14	Holstein 1-day old	Male	Transversal diaphyseal fracture of right ulna and radius	(3), Occasionally there is lameness during the walk. general condition is good
15	Holstein 2-days old	Female	Mid diaphyseal spiral fracture on the right tibia.	(2), no walking problem and general condition is good.

Interlocking Nail: Third generation ILN and instrumentation were used in this study. The equipment was manufactured by Orthovet (Izmir, Turkey). Each ILN had a trocar tip on one end and a negative thread on the other end to receive the jig used for cortical screw placement and three screw holes including two distal and one proximal. The ILNs could be inserted with a Jacobs chuck in a retrograde direction with use of a removable tip and generally Steinman nails were inserted instead of interlocking screws. In order to determine the length of the interlocking nail to be used, radiographs of the contralateral bone on the intact side were taken or the length of the fracture fragment was measured during the operation. Seven ILN lengths (150, 160, 170, 180, 190, 210 and 230 mm) and diameters of six, eight, nine and 10 mm were used in this trial.

***Surgical Technique*:** Surgical technique followed published procedures by Arıcan *et al*. (2017). Preoperative meloxicam (0.5 mg / kg BW, Maxicam® inj., Sanovel, Istanbul, Turkey) was given subcutaneously before surgery. Anesthesia was induced with 0.2 mg/kg intravenous xylazine hydrochloride (Alfazyne 2% 20 mg/ml, Egevet, Izmir, Turkey) and 2 mg/kg ketamine hydrochloride (Alfamine 10%, 100 mg/ml Egevet). After 10 mins, anesthesia was maintained with two to four percent isoflurane in oxygen (Aerrane, Baxter, Ontario, Canada). Craniocaudal and mediolateral radiographs were taken postoperatively to view the results of the procedure and combination of 10.000 IU benzyl procaine penicillin G and 10 mg dihydrostreptomycin via IM route daily for five days (Reptopen-S® inj, Ceva-DIF, Istanbul, Turkey) and 0.4mL/10 kg SC Meloxicam 20 mg was administered postoperatively for two days after surgery.

Outcome: Return visits of the surgery cases were requested from owners for follow up radiographs on 8-10 weeks to assess fracture healing for some cases. For cases not brought to the clinic, their clinical status was checked by phoning the clients (Table 1). The clients, whose settlements are far away from the clinic, reported by phone whether the leg was used or not.

Evaluation of Fracture Healing: Bone healing and pain levels were confirmed by radiographic evidence. Fracture healing was classified by the use of a modified Meynard and Magnin (1994). The method assessed the quality of fracture reduction, the quality of healing of the interosseous space including its size, space, lack of bony substance, callus density and periosteal callus volume noted as normal or exuberant (Bhat *et al*., 2014).

***Functional Outcome*:** The limb was scored as 1, excellent with a total absence of lameness, 2 as good where the animal can use the limb, 3 as fair with only occasional lameness and 4 or poor where the animal could not use the limb. Intraoperative technical errors during surgery or the incorrect choice of implants and postoperative complications including implant failure, delayed healing and non-union were recorded. Delayed union was defined as a fracture that had not healed within three months and non-union as a fracture that had not healed within five months. Implant failure was defined either as the breakage of the nail before fracture union or removal of the ILN and replacement by another type of fixative. ILN was left on without removal.

Statistical analysis: Outcome was assessed through recheck examinations by the primary surgeon at least until radiographic healing. Further follow-up was by re-examination or telephone interview by the primary author. The distribution of calves with respect to fracture type, sex, age, fracture location in the involved bones and outcome of treatment was reported as a percentage.

Results

Of the 48 calves that had fracture complaints, metacarpal fractures (60.4%) were the most frequent fractures. This fracture was followed by femur (16.6%), tibial (12.5%), metatarsus (4.1%), humeral (4.1%) and radial (2.0%). Operative procedure options including interlocking were presented to the owner for all long bone fractures. Twenty-six of the 48 fractures were treated conservatively with synthetic or PVC-supported bandage (54.1%). Two clients (4.1%) did not accept the proposed treatment. Amputation was performed in one calf (2.08%) due to osteomyelitis.

Nineteen calves (39.5%) received surgical repair, including 15 where interlocking nails were placed and four where intramedullary nails were selected as the treatment because the fracture line was very distal.

Classification of Fracture: In the 15 ILN surgical cases, fractures were located in the humerus (13.3%), antebrachium (13.3%) (Fig.3), femur (46.6%) (Fig.4.5) and tibia (26.6%) (Fig.6) and mid-diaphyseal transversal or oblique fractures were seen in nine (60%) and distal diaphyseal fractures (40%) in six cases (Table 1). Humeral and open metacarpal fractures coexisted in one patient.

Outcome: Ten of the 15 calves (66.6%) that underwent ILN recovered without any complication in the postoperative period (Fig.3,4,5,6). In five cases (33.3%), there were some wound complications due to various causes such as infection and opening of the sutured area, which resulted in being sent to slaughter in the post-operative period.

Evaluation of Fracture Healing and Functional Healing: In six cases evaluated within the scope of the study, the degree of fracture healing could not be evaluated due to the client not returning with the animal in the post-operative period but, based on the information obtained from the animal owner, it was concluded that they were able to successfully use the extremity.

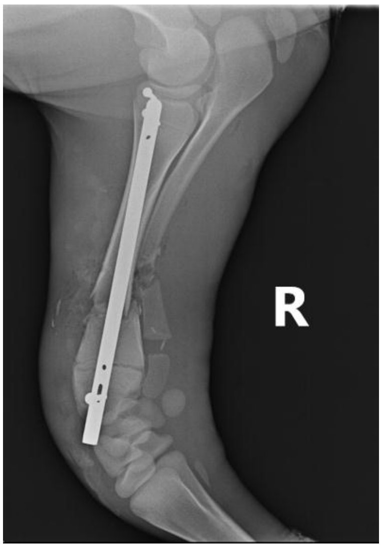

Figure 3 Immediately postoperative radiographs of case 14. The diaphyseal fracture has been repaired using an 8–160-mm interlocking nail. Medio-lateral position.

Figure 4 Postoperative radiographs of case 5. The diaphyseal fracture has been repaired using an 10–180-mm interlocking nail. Medio-lateral position.

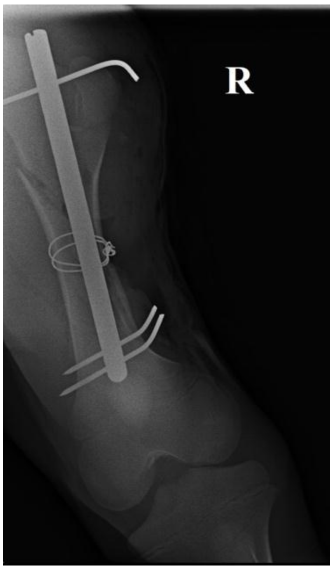

Figure 5 Postoperative radiographs of case 13 (Holstein 7-day old). The diaphyseal fracture has been repaired using an 10–180-mm interlocking nail. Cranio-caudal position.

Figure 6 Postoperative radiographs of case 10 (Simental 2-day old). The diaphyseal fracture has been repaired using an 10–190-mm interlocking nail. Medio-lateral position.

Implant Problems: There was no bending or breaking complication in the interlocking nails.

Locking Errors: In most of the cases, there was a problem caused by the passage of the screw or pin. While the screw or pin passage was provided at the proximal end of the ILN, it was observed that there were no passages through the distal holes.

Discussion

It was observed that ILN was a good option in calves with fracture treatments because they were in the same axis with intramedullary pins for the bone and they shared the burden in the tubular bones jointly (Durall *et al*., 1993). Although many methods are performed for fracture fixation in calves, choice of the method or material is dependent on fracture type and localization, size, age and temperament of the animal and economic status of the owner (Lillich *et al*.,1999) because no material or technique is perfect alone and all have advantages, disadvantages and risks (Gülaydın and Sarıerler, 2018). Among these, the cylindrical pins used such as the multiple Steinmann pins can control the bending force but because they do not fully grasp the medulla of the bone they cannot prevent rotation that may occur at the fracture site (Marturello *et al*., 2019). Complications such as detachment of fracture fragments by movement of the animal, displacement of the pin and related infection formation have also been reported (Arıcan *et al*., 2013). In the post-operative period animals treated with intramedullary pins require bandaging, unlike ILN cases, which is an advantage of ILN treatment.

Interlocking nails allow rigid fracture stabilization and present biomechanical advantages when compared to other immobilization techniques. The intramedullary nail is placed in a natural position relative to the biomechanical axis of the bone, neutralizing the bending forces across the bone fragments. The transverse locking screws secure the nail relative to the main bone parts to resist compressive and rotational force (Moses *et al*., 2002; Wheeler *et al*., 2004). One of the major disadvantages of this method is the need for fluoroscopic or radiological control due to the difficulties in insertion of transversally inserted screws (Bellon, and Mulon, 2011; Arıcan *et al*., 2017). The guide is to help better locking fixation (Wheeler *et al*., 2004). In the present study, Steinmann pins were used for locking despite the use of screws. No problems were encountered at the entrance to the proximal end of the intramedullary pin but there could be a problem in the passage through the distal holes.

It has been reported that ILN has been successfully used for diaphyseal fractures of the femur in calves (Ferguson, 1994). Several authors note that it can be performed in a shorter time compared to other treatment methods such as intramedullary pins, plating and external fixator application for long bone fractures (Mulon *et al*. 2015; Feist *et al*., 2019). Plating causes more tissue damage than intramedullary pin and circular external fixator application. It is also reported by the same authors that endosteal blood circulation is impaired in intramedullary pin applications and periosteal circulation is disturbed in plating.

Studies have shown that healing in intramedullary pin stabilization occurs within eight to 16 weeks with bone callus (Mulon *et al*., 2015). Considering a cylindrical structure, a hole greater than 30% of its diameter will generate stress as a fracture potential in the body. In ILN, the screw holes are always greater than 30% of the pin diameter and this ratio reaches 50% for small diameter pins (Mulon *et al*., 2015) Depending on the durability of material, the diameter of the pin, the external diameter of the screw and the ratio of the pin diameter, the screw holes on the pin to be used in fixation have to be at least two cm away from the fracture line (Durall *et al*., 1993; Marturello *et al*., 2019). The approach to the diaphysis of the humerus and femur is usually lateral and medial of the tibia. Both the intramedullary pin and the interlocking pin can be inserted proximally to the fracture site normograde distally to the retrograde. In the present study, the interlocking pins were placed retrograde.

Although the healing process of the fracture in ILN use is longer than for external fixation, the results are satisfactory, as the bone to interlocking pin weight sharing ratio increases as the bone heals (Durall *et al*., 1993; Dueland, 1998; Marturello *et al*., 2019). This is because callus formation at the fracture site increases the immobility rate and transfers weight from the implant to the bone, resulting in less fatigue of the implant. In addition, the holes in the interlocking pin are not placed as near or close to the fracture line, minimizing this stress (Dueland, 1998).

The ILN application has some disadvantages. The screw or pin can be difficult to insert through the holes on the interlocking pin therefore frequent x-rays can be required to find the holes. Pin breakage can also encountered (Muir and Johnson, 1996; Marturello *et al*., 2019). In this study, the pin was used for fixation and it was applied directly, so there was no problem for fixation. Rotation problems were also considered, as well as the need for special tools to insert and fasten the screws, being most usable in mid diaphyseal fractures and because of the stress-increasing effect of the holes in the bone and pin, causing fatigue fractures (Dueland, 1998; Duhautois, 2003). Interlocking pins are used successfully in diaphyseal fractures of long bones including the femur, tibia and humerus but metaphyseal or epiphyseal fractures are not suitable because they cause rotation. The complications of ILN are mostly technical reasons such as placing the screws close to the fracture line or leaving them loose and not choosing the appropriate sized pin. ILN fixation has been used frequently in human medicine in recent years. Although the operation was short and the fixation was performed successfully, the low success rate of 66.6.% was attributed to the lack of adequate environment in the post-operative period. This led to the conclusion that long-term maintenance conditions were not considered important by the animal owners and the success rate would increase with improvement of the postoperative environment. In some cases, clients were unable to meet treatment expenses and patients were not able to reach the desired level of live weight after treatment.

In conclusion, this study showed that calves fractures often occur during birth and are due to inappropriate assistance which has the potential to cause severe economic loss to the cattle industry. The interlocking pin is a safe and effective alternative to plating or external fixation. It could be widely used for calf orthopedics under good post-operative conditions.

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