CASE REPORT

Tibial fracture repair with angle-stable interlocking nailing in 2 calves

Danielle M. Marturello DVM | Krista M. Gazzola DVM | Loïc M. Déjardin DVM, MS, DACVS, DECVS

Department of Small Animal Clinical Sciences, Michigan State University, East Lansing, Michigan

Correspondence
Loïc M. Déjardin, Department of Small Animal Clinical Sciences, College of Veterinary Medicine, Michigan State University, East Lansing, MI 48824.
Email: dejardin@cvm.msu.edu

Abstract
Objective: To report tibial fracture repairs with I-Loc angle-stable interlocking nails (AS-ILN) in 2 calves.
Study design: Clinical case reports.
Animals: One 5-day-old Holstein calf and one 3-month-old beefalo calf.
Methods: In a 50-kg Holstein calf, a proximal juxtametaphyseal comminuted tibial fracture with tibial tuberosity slab fracture was repaired with an 8–160-mm I-Loc nail and 2 cortical lag screws. In an 89-kg beefalo calf, a long oblique middiaphyseal tibial fracture was repaired with an 8–185-mm I-Loc nail and 5 double loop cerclage wires. In each case, an I-Loc AS-ILN was selected because unique biomechanical challenges precluded treatment with traditional osteosynthesis methods, such as external coaptation or plate fixation.
Results: No complications were diagnosed, and clinical union was documented 4 weeks after surgery in both cases. Axial growth continued in both calves, with no evidence of angular limb deformity at 7- and 6-month follow-up.
Conclusion: This is the first report describing the use of the I-Loc nail in a bovine species. This application led to uncomplicated healing of tibial fractures and continued growth in both young calves described here.
Clinical significance: Interlocking nailing may provide an effective and safe alternative for osteosynthesis of tibial fractures in young calves. Insertion of the AS-ILN across the center of the proximal tibial physis of a rapidly growing calf does not seem to alter its growth potential.

1 | INTRODUCTION

Tibial fractures reportedly account for 15%–41% of long-bone fractures in cattle, regardless of age. In neonates, these typically result from forced extraction during birth or trauma from the dam. In young cattle, tibial fracture can occur during transport, in the pasture, or in cattle sheds. Conservative treatment generally involves stall confinement and/or use of external coaptation such as a Thomas splint-cast combination. Although that technique has yielded positive results in some studies and is the preferred method of treatment by some investigators, others have reported that conservative treatment does not result in acceptable bone healing. Indeed, it has been reported that, after external coaptation, animals sustained severe angular deformity of the affected limb with persistent lameness despite bone healing.

It is difficult to report accurately the outcome of conservative treatment for larger cattle because euthanasia is often recommended because of the limitations of this approach. Similar limitations of conservative management have been reported in double-muscled breeds such as the Belgian white and blue, in which the sharp decrease in muscle circumference at the level of the tibia may create a mechanical predisposition to diaphyseal fractures regardless of bodyweight. Indeed, failure of conservative treatment of tibial fractures, such as splinting, is reported even in newborn calves weighing less than 80 kg.
Four common reasons limit the surgical treatment of production animals. First, financial costs often outweigh the commercial value of the animal. Second, fractures that involve the metaphysis with physeal damage can result in long-term limb shortening or angular deformities and hinder ambulation. Third, currently available orthopedic armamentarium for long-bone osteosynthesis in heavier animals or double-muscled breeds can mean that surgical repair is not attempted because of the predisposition to implant failure. Fourth, immature bone has intrinsically weak mechanical properties across species. Therefore, one could speculate that, in young animals, failure of plate osteosynthesis via screw pullout represents a serious challenge.

Results of surgical treatments for skeletally immature bovine fractures provide evidence that the best results are achieved with plate and clamp rod techniques, although alternatives including intramedullary pinning or external skeletal fixation (ESF) have also been employed. Complication rates of up to 74% after surgical repair have been reported in some studies, so neonatal bovine fractures can potentially carry a guarded prognosis and may result in euthanasia. Should biomechanical challenges be overcome and clinical outcome improved by using alternative fixation methods, surgical treatment in valuable animals might be considered a viable option. Although interlocking nail (ILN) stabilization has been successful in small animals, to the best of the authors’ knowledge the clinical use of an angle-stable ILN (AS-ILN) for long-bone fixation in production animals has yet to be described. This report details the successful treatment and clinical outcome of 2 tibial fractures in calves by using the I-Loc (Biomedtrix, Whippany, New Jersey) intramedullary fixator.

2 | CLINICAL REPORT

2.1 | Case history

2.1.1 | Case 1

A 5-day-old, 50-kg female Holstein calf was evaluated at Michigan State University for a non-weight-bearing left hind limb lameness after assisted vaginal delivery with obstetrical chains. From results of orthogonal radiographs (Figure 1), the calf was diagnosed with a proximal tibial metaphyseal fracture that was (1) moderately displaced, (2) highly comminuted, and (3) included a large cortical slab caudal and distal to the tibial tuberosity. Computed tomography (CT) was recommended to characterize further the fracture pattern and revealed that the slab fracture affected the medial tibial cortex (Figure 2).

2.1.2 | Case 2

A 3-month-old, 89-kg intact female beefalo calf was evaluated at Michigan State University for a non-weight-bearing left hind limb lameness after injury sustained from a falling bale of hay. Results of orthopedic examination provided evidence of a middiaphyseal tibia fracture. Orthogonal radiographs of both tibiae were obtained for diagnosis and surgical planning purposes. Middiaphyseal spiral fracture was diagnosed with numerous fissures expanding from the fracture edges into the...
proximal and distal segments (Figure 3). The relative fracture pattern simplicity did not warrant CT.

2.2 | Surgical planning

2.2.1 | Case 1

Computed tomography files were uploaded to image processing software (Mimics; Materialise, Leuven, Belgium) for segmentation. Radiographs were imported into surgical planning software (OrthoView VET, Hampshire, United Kingdom) for simulated fracture reduction as well as selection and evaluation of various implant options. Several implants were considered for fixation. Plating options included 3.5-mm and 4.5-mm locking compression plates (LCP; DePuy Synthes, West Chester, Pennsylvania), double plating with 3.5-mm LCP, or orthogonal plating with 3.5-mm LCP (Figure 4A-D). Plate osteosynthesis was deemed inadequate for at least 1 of the following reasons: (1) the short proximal metaphyseal segment would limit the number of plate screws to 3 at the most, (2) bending the plate(s) to accommodate the pronounced proximal metaphyseal flare would inevitably direct locking head screws (LHS) across the physis or require using unacceptably short screws, or (3) using cortical screws aimed below the physis would increase the risk of screw pullout, particularly considering that limited available screw lengths would preclude bicortical fixation (Figure 5A). Double medial plating was also deemed inadequate because the narrow bone could not accommodate both implants (Figure 4C). Finally, although orthogonal plating is mechanically stronger, this was not considered a valid option because of the tibial tuberosity fracture.

Because of the limitations of plate osteosynthesis, interlocking nailing was evaluated as an alternative option. In OrthoView, an 8–160-mm I-Loc ILN was templated. That nail would bridge the fracture gap while maintaining the locking bolts below the proximal physis, fully engaged in trabecular bone (Figure 5B). Other benefits of interlocking nailing were also carefully considered in our implant selection, including the nail intramedullary location, its relatively larger dimension compared with a size matched bone plate, and the angle-stable design of the I-Loc. Finally, because cost is often a limiting factor in decision making for}

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**FIGURE 3** Orthogonal radiographic views of the left tibia in case 2 showing a middiaphyseal spiral fracture with fissures expanding from the fracture edges into the proximal and distal metaphyses

**FIGURE 4** OrthoView digital planning software was used to evaluate various fixation methods in both cases. In case 1, plating options included a 3.5-mm locking compression plate (LCP; A), a 4.5-mm LCP (B), double plating with 3.5-mm LCP (C), and orthogonal plating with 3.5-mm LCP (D). For various biomechanical reasons (see article text for details), each of these options was deemed inadequate for fixation.
production animals,\(^2\) nail fixation was an economically attractive alternative to locking plate osteosynthesis.

2.2.2 | Case 2

Radiographic images were imported into OrthoView for surgical planning. Because of the reconstructible fracture pattern, the surgical plan involved fracture reduction and stabilization with double loop cerclage wires along the spiral interface (2) as well as proximal (1) and distal (2) fissures to counteract shear forces. Because this was a juvenile calf with structurally stronger bone compared with a neonate, both neutralization plate and ILN were considered viable options to complement cerclage wiring. Nonlocking plates (limited bone contact dynamic compression plates or dynamic compression plates) were initially deemed appropriate because the risk of screw pullout was mitigated by the structurally stronger bone. In addition, cortical screws could be aimed away from both physes and joints. However, available screw lengths for 3.5 or 4.5-mm plates were too short to allow for bicortical purchase, so 3.5 or 4.5-mm LCP were considered because LHS would allow for monocortical purchase with available screw lengths. However, as described for case 1, the proximal plate bend to accommodate the metaphyseal flare would have directed the screws across the physes. This would increase the risk of iatrogenic, asymmetrical premature physeal closure and therefore predispose the animal to angular limb deformity.

After considering AS-ILN advantages and limitations of plate osteosynthesis, I-Loc nail fixation was deemed optimal. In addition, fracture reconstruction using cerclage wires would allow load sharing, thus shielding the ILN from excessive forces in this heavier calf. Finally, just as with case 1, the ILN was financially more economical compared with other osteosynthesis methods.

2.3 | Surgical procedure

2.3.1 | Case 1

According to established protocols in place at our institution, the calf was premedicated with 5 mg/kg ketamine IV and 0.2 mg/kg diazepam IV and induced with IV 4 mg/kg propofol; anesthesia was maintained with isoflurane in oxygen. Ampicillin 22 mg/kg IV was given intraoperatively every 90 minutes throughout the procedure, and 0.01 mg/kg buprenorphine was administered IV for pain management.

The calf was not fasted prior to surgery. The left hind limb was prepared for routine aseptic surgery by using a hanging limb technique. In the operating room, the calf was placed in dorsal recumbency on the surgical table, secured with surgical bean-bag positioners, and then draped by using sterile technique. A medial parapatellar approach similar to that used in dogs\(^22\) to the left stifle was completed, extending ~4 cm distal to the fracture. The sartorius muscle insertion was elevated, and the muscle was retracted caudally to expose the craniomedial aspect of the tibia. A separate incision was then made over the medial malleolus. The tibial tuberosity slab fracture was reduced first and was secured by using two 4.5-mm cortical screws with washers placed in lag fashion. Pilot holes were not tapped because of the bone softness of this immature patient. The patella was then luxated laterally to expose the cruciate ligaments and tibial intercondylar eminences.

Interlocking nail insertion into the proximal fragment was performed with the stifle in hyperflexion. The cranial and caudal cruciate ligaments were carefully separated from one another to expose the nail insertion site immediately cranial to the tibial eminences. This location represented the center of the tibial plateau in both sagittal and transverse planes. The proximal epimetaphysis was gradually opened by using Steinmann pins ranging from 3.2 to 5.5 mm in diameter. Next, the opening was enlarged sequentially by pushing 6-, 7-, and then 8-mm nails through the initial epiphyseal pilot hole. Although nail insertion requires that a bone tunnel be cut in the proximal metaphysis with an awl, this was not required in this case because of the bone softness. Rather, nails of increasing diameters were progressively impacted to create a compact cancellous shelf in the metaphysis and therefore improve bolt fixation.\(^23\)

To achieve reduction of the diaphyseal portion of the fracture without risk of crushing the proximal fragment with bone holding forceps, a 20-mm ostectomy of the distal fragment was performed by using a sagittal reciprocating saw.
Corticocancellous chips and fracture hematoma were preserved for grafting. After reduction, the nail was inserted into the distal fragment through the reduced fracture site, ensuring proper rotational alignment as well as alignment in the sagittal and transverse planes. Deep nail seating is most often achieved by using a reamer that cuts a bone tunnel in the distal metaphysis. As previously described, a compacted cancellous shelf was created in the distal metaphysis by sequentially impacting nails of increasing diameters (6–8 mm). Intraoperative fluoroscopy was used to ensure that the distal physis was not violated. To optimize the length of the bolt anchored in the compacted metaphyseal bone, the nail was rotated until the plane of the locking bolts was oriented toward the caudolateral tibial cortex. The bolts were then inserted in sequence from proximal to distal by following established protocols (https://biomedtrix.com/I-Loc). The previously harvested corticocancellous bone chips and fracture hematoma were placed around the fracture site. Routine closure in layers by using appropriately sized absorbable sutures concluded the procedure. A sterile dressing was applied over the incision prior to postoperative imaging.

2.3.2 | Case 2
The calf was fasted prior to surgery. By following the same protocols and aseptic preparation as described for case 1, the calf was placed in dorsal recumbency on the surgical table, secured with surgical bean bag positioners, and then draped by using sterile technique. A standard approach to the medial shaft of the left tibia was completed to expose the fracture site. After reduction, five 1.2-mm double loop cerclage wires were evenly placed around the diaphysis. By using appropriately sized absorbable suture materials, the incision was closed routinely in layers, leaving ~4 cm open distally to allow bolt insertion. Next, a medial parapatellar arthrotomy was completed as described for case 1, and the stifle was placed in hyperflexion. The cruciate ligaments were identified and meticulously separated to allow insertion of a large intramedullary pin just cranial to the tibial eminences. The proximal epimetaphysis was prepared by using sequentially larger Steinman pins (up to 5.5 mm) and then an awl (up to 8 mm). Next, a trial nail was used cut a bone tunnel in the distal metaphysis up to the physis. An 8–185-mm I-Loc was inserted normograde and then impacted into the distal bone tunnel. The nail was secured by using 2 bolts in the proximal and distal metaphyses. Routine closure in layers by using appropriately sized absorbable suture materials completed the procedure. A sterile dressing was applied over the incision prior to postoperative imaging.

2.4 | Postoperative care
Wound dressings were changed as required when they became soiled. Calves were administered ampicillin 10 mg/kg IM once daily as well as meloxicam 1 mg/mg orally every 48 hours. The second calf was also administered ceftiofur 2.2 mg/kg IM once daily. The neonatal calf was fed milk replacer every 4–6 hours, whereas the juvenile calf was fed grass, hay, and pellets. The calves were kept indoors on pine chips in small pens and assessed daily for pain, weight bearing, and evidence of infection. Both calves were standing and ambulating the day after surgery. To allow bottle feeding, the Holstein remained in the hospital for 25 days. During this time, repeat imaging was performed to monitor her closely for implant related complications. In contrast, the beefalo calf was discharged 3 days postoperatively because she was eating on her own, and repair failure was of less concern because stable cortical continuity was fully restored.

2.5 | Postoperative assessment
Tibial postoperative orthogonal radiographs were obtained in both calves (Figures 6–7) and were assessed for limb alignment, fragment apposition, and implant position. Because of the pronounced curved profile of the tibial plateau, the growth plate angle (GPA) rather than the tibial plateau angle was used to evaluate alignment. First, the tibial diaphysis anatomical axis was defined as the line joining the midpoint between the tibial eminences and the uppermost aspect of the tibial ridge (transverse plane). The GPA was calculated as the angle between the plane of the proximal tibial growth

![Figure 6](https://example.com/figure6.png) Immediately postoperative radiographs of case 1. The diaphyseal fracture has been repaired using an 8–160-mm I-Loc nail. The tibial tuberosity slab fracture has been reduced by using two 4.5-mm cortical screws with washers placed in lag fashion. Limb alignment, fragment apposition, and nail and bolt locations were deemed appropriate. Note the presence of autogenous corticocancellous bone chips obtained after morselization of the ostectomized comminuted segment.
plate and the tibial anatomical axis on mediolateral and craniocaudal projections (Figure 8). The GPA were compared to those of the contralateral limb as well as to those of subsequent radiographs to evaluate for potential angular deformities. Subjective assessment of fragment apposition as well as implant placement was also performed. Implant positioning was considered appropriate when the nail was aligned with the tibial anatomical axis with the bolts located in the metaphyses (ie, not bridging the epiphyseal plates).

In case 1, because of the animal’s age, radiographic evaluation was performed at 10 days and 3 weeks to rule out possible early complications, including implant or bone failure. Radiograph and CT images of both tibiae were obtained at 8 and 27 weeks to evaluate bone growth and possible tibial length discrepancies. Because of concerns about potential growth disturbances, CT was used to determine the ratio between the nail and proximal tibial physis cross-sectional areas. The physeal area was calculated in Mimics software (Figure 9). Thereafter, the calf’s size and weight (~210 kg) precluded CT evaluation.

In case 2, because of the expected slower growth rate of this older calf and the lower risk of repair failure inherent to both diaphyseal reconstruction and greater bone strength, follow-up radiographic evaluations were performed less
frequently, at 4 and 19 weeks. In the absence of CT data, the nail-to-physeal area ratio was extrapolated by using the following method. First, by using CT data from case 1, the ratio between the physeal area and that of a best fit circle was calculated. Next, the mediolateral physeal width of case 2 was used to calculate the area of a best fit circle around the physis. By assuming similar tibial geometry between the 2 cases, the area ratio that had been previously determined in case 1 was used to compute the physeal area of case 2 and, eventually, the nail-to-physis area ratio.

In both cases, follow-up radiographs were evaluated for (1) limb alignment, (2) tibial lengths, (3) bone healing, and (4) complications. Limb alignment was restored and maintained in both sagittal and transverse planes over time in both cases. Indeed, postoperative GPA remained within 2° of that of the contralateral tibia at each time period (Figure 8).

Tibial length was measured on orthogonal projections of both limbs by using predetermined landmarks. The initial 20-mm shortening of the left tibia in case 1 was maintained at each radiographic follow-up. Even though there had been original length discrepancy, no difference was noted between left and right tibiae, and no difference in limb length between left and right tibiae was noted at any time point for case 2.

Bone healing in both cases can be seen in Figure 10. Clinical union, defined as presence of a bridging callus on 3 of 4 cortices on 2 orthogonal radiographic projections, was recorded at 4 weeks postoperatively in both cases.

Complications were not documented in these 2 cases. In particular, there was no evidence of implant failure, angular deformity, or osteomyelitis in either case at any time point.

3 | DISCUSSION

Although the proximal tibial growth plate was violated in both calves, comprehensive surgical planning and careful modification of a surgical technique commonly used in small animals allowed for normal axial growth without complications or continued lameness.

Tibial fractures make up a large portion of fractures seen in cattle of all ages, with their location and pattern being age...
dependent. In newborn calves (case 1), tibial fractures typically affect the junction between the metaphysis and diaphysis, where woven cancellous bone morphs into lamellar cortical bone.\textsuperscript{18,25} It has been postulated that this transition is a point of mechanical weakness during axial loading,\textsuperscript{18} as seen with traction during dystocia. In contrast, fractures in older animals (case 2) most commonly affect the diaphysis and frequently occur during transport or in pastures.\textsuperscript{5} These animals have structurally stronger bone than neonates as well as less growth and weight gain potential, which may influence implant selection by a surgeon.

In addition to age, potential growth rates were also considered during preoperative planning because variations exist between breeds. Holstein calves typically have an early biphasic growth from birth to 8 weeks of age, gaining approximately 0.3 kg/day for the first 4 weeks then approximately 1.4 kg/day until 8 weeks.\textsuperscript{26} The Holstein calf gained approximately 6.8 kg in the 4 weeks it took to achieve clinical union (\(-0.23\) kg/day), reached 100 kg at 8 weeks (\(-1.4\) kg/day), and then 193 kg at 24 weeks (\(-1.2\) kg/day). In contrast, with an average daily weight gain of approximately 0.6 kg from birth to weaning at 6 months, beefalos have a more consistent and slower growth rate.\textsuperscript{27} The beefalo described in this report gained \(-136\) kg from birth to 8 months (\(-0.6\) kg/day). This translated into nearly 17 kg approximately 6.8 kg in the 4 weeks it took to achieve clinical union (\(-0.23\) kg/day), reached 100 kg at 8 weeks (\(-1.4\) kg/day), and then 193 kg at 24 weeks (\(-1.2\) kg/day). In contrast, with an average daily weight gain of approximately 0.6 kg from birth to weaning at 6 months, beefalos have a more consistent and slower growth rate.\textsuperscript{27} The beefalo described in this report gained \(-136\) kg from birth to 8 months (\(-0.6\) kg/day). This translated into nearly 17 kg weight gain (more than twice that of the Holstein) during the same 4-week period from surgery to clinical union (Figure 11). Because of the large weight gain between fracture fixation and anticipated clinical union (4–8 weeks), interlocking nailing appeared more mechanically sound than plating in both cases.

Described treatments for juvenile bovine tibial fractures include bone plates, intramedullary rods, and ESF.\textsuperscript{16,17} Reports detailing these fixation methods describe high complication rates and overall poor clinical outcomes. After ESF pin removal in 1 study, cortical fracture occurred in 9% of calves.\textsuperscript{2} In another study evaluating femoral fractures in newborn calves, only 43% had a successful outcome, defined as discharge from the hospital and ability to walk 6 weeks postoperatively.\textsuperscript{15} Because bovines must be able to ambulate on all 4 limbs, these complications may result in euthanasia.\textsuperscript{16}

In small animals, long-bone osteosynthesis with an AS-ILN has been associated with excellent clinical outcomes and low complication rates.\textsuperscript{20,21} Unlike eccentrically applied plates, the ILN intramedullary location shields the implant from large bending moments. Furthermore, ILN have substantially larger area moments of inertia than size-matched bone plates and therefore resist deleterious cyclic bending moments more effectively. An added advantage of the intramedullary location is that repair failure via screw pull out seen with plates, particularly when used in juvenile bone, is virtually eliminated. Furthermore, the I-Loc unique angle-stable locking mechanism design limits the risk of bolt-nail interface decoupling and, therefore, bolt pull out. This design also provides construct torsional and bending stability and thus limits deleterious shear motion between bone fragments. A new ILN featuring multiple cannulations throughout the nail shaft was recently designed for the specific treatment of tibial fractures in buffalos.\textsuperscript{28} However, a cadaveric study provided evidence that nail or construct failure occurred at loads ranging from 8% to 42% of those of an intact bone.\textsuperscript{28} The safe use of a similar design described 2 decades ago\textsuperscript{29} was limited to cases in which full cortical reconstruction could be achieved, presumably because of the risk of nail fracture through the locking cannulations.\textsuperscript{30}

Each fracture described in this report had unique characteristics that precluded plate osteosynthesis. Having considered the high complication rates associated with traditional fixation techniques in production animals, we believe nail osteosynthesis with the I-Loc was an optimal repair option. Plate osteosynthesis was ruled out in both cases. For case 1, the poor material and structural strengths of neonatal bones increased the risk of implant failure via screw pullout.\textsuperscript{13–15} This is particularly true when considering commercially available screw lengths for 3.5- and 4.5-mm plates. Although nonlocking plates would have been appropriate in case 2 solely on the basis of diaphyseal reconstruction and bone strength, the longest available screw remained too short to achieve bicortical purchase. With room for only 2–3 screws per fragment, monocortical fixation was considered unacceptable.

After ruling out nonlocking plate osteosynthesis in both fractures, LCP fixation was considered. However, the proximity of the screws to the proximal physis and stifle joint precluded safe use of LHS. Indeed, a pronounced plate contour would be required to follow the proximal tibial metaphyseal flare in both calves. Because LHS are inserted at a fixed angle normal to the plate surface, this would result in 1 of 2 outcomes. First, the most proximal screw would cross the physis and violate the joint. Mitigating this by selecting a shorter screw was not a viable option because it would

**FIGURE 11**  Body weight over time from birth to 32 weeks for both calves. The times of surgery and clinical union are indicated by arrow heads and open circles, respectively. Asterisks indicate actual recorded body weights. Missing data points were extrapolated on the basis of expected gains as reported in the literature.\textsuperscript{26,27}
compromise fixation. Second, any screw of appropriate length would cross the physis near the medial tibial cortex, thus increasing the risk of iatrogenic premature asymmetrical physeal closure, potentially leading to varus deformity. One theoretical advantage of LCP constructs is that precise contouring is not required. However, because of the pronounced flare of the tibial metaphyses in these cases, using a straighter plate for the purpose of directing screws below the physis would potentially carry several biological and mechanical risks. These include (1) excessive soft tissue tension over the plate that could lead to wound dehiscence, (2) eccentric loading of the plate that would subject the LCP to higher bending moments and, therefore, increase the risk of fatigue failure, and (3) substantial increase of the LHS working length, which has been shown to decrease construct stability and also increase the risk of screw failure significantly.31 For these reasons, LCP osteosynthesis was also ruled out in both cases.

Because of conventional fixation limitations2,16 and the biomechanical benefits of interlocking nail osteosynthesis, fracture repair with an I-Loc was elected in both calves. Although careful consideration was given to the risk of iatrogenic damage to the proximal epiphyseal plate, this was not considered a limiting factor in either case. First, the I-Loc footprint relative to the proximal physeal area was deemed inconsequential. Although the proximal physeal area was approximately 4000 mm² in both cases, the 8-mm I-Loc area is ~50 mm², which represented less than 1.3% of the physeal area. One can speculate that the pressure generated by the physis during growth would overcome the strength of a small epiphysiodesis bridge that could develop postoperatively. Indeed, in 1 study comparing growth of axially loaded rabbit femoral physes, intramedullary pin implantation did not alter the growth process.32 Second, the I-Loc’s central location with respect to the growth plate made asymmetrical premature physeal closure and subsequent angular deformity highly unlikely. Indeed, both calves continued normal axial growth without evidence of deformity for the entirety of follow-up. The original length discrepancy (20 mm) from the ostectomy in case 1 was not regained. This contrasts with the “overgrowth” phenomenon typically reported in children after fracture repair.33,34

In both cases, the nail insertion point differed from that recommended in small animals in which the nail typically enters the tibial plateau directly cranial to the cranial cruciate ligament footprint. In contrast, both nails were inserted immediately cranial to and between the tibial eminences at a point located directly above the anatomical axis of the tibial diaphysis. The rationale for selecting this central location was threefold. First, it optimized the length of the locking bolts supported by the cancellous envelope of the metaphyses and, therefore, protected them from bending, which in turn extended their fatigue life under axial loading.35 Central rather than medial placement of the nail also resulted in an even load distribution of the bolt cis and trans sections, thereby likely improving overall fixation. Second, it avoided the narrow (and in case 1 weaker) tibial crest, which further strengthened bolt purchase and support. Third, nail placement immediately cranial to and between the tibial intercondylar eminences, located near the center of the femorotibial articular surface, likely provided a mechanical advantage by reducing bending moments on the nail during loading.

This report documents the successful use of an I-Loc AS-ILN for the treatment of 2 different tibial fracture configurations in 2 young, growing calves, each with its own surgical challenges. Because of the high percentage of complications and poor outcomes associated with conventional fixation techniques, interlocking nailing of tibial fractures in immature production animals by using the I-Loc provides a safe and effective alternative to osteosynthesis with plates or ESF.

CONFLICT OF INTEREST
Loic Déardin is the inventor of the I-Loc nail. As such, he receives royalties from MSU and teaching honorarium from BioMedtrix. Danielle M. Marturello and Krista M. Gazzola declare no conflicts of interest related to this report.

REFERENCES


