The Journal of Veterinary Medical Science

NOTE

Surgery

Influence of transfixation pinning and casting (TPC) configurations on treatment outcomes in bovine tibial fracture

Kaoru HATATE[1,4,5)], Nao TSUZUKI[1)], Ayako KAJIHARA[2)], Bhuminand DEVKOTA[4,6)], Kazuya TAKEHANA[4,7)], Reiichiro SATO[8)], Kimie IINO[1)], Takahiro AOKI[3)], Eiji TAKAHASHI[1)] and Norio YAMAGISHI[1,3–5)]*

1)Department of Veterinary Medicine, Obihiro University of Agriculture and Veterinary Medicine, 2-11, Inada, Obihiro, Hokkaido 080-8555, Japan
2)Veterinary Medical Center, Obihiro University of Agriculture and Veterinary Medicine, 2-11, Inada, Obihiro, Hokkaido 080-8555, Japan
3)Research Center for Global Agromedicine, Obihiro University of Agriculture and Veterinary Medicine, 2-11, Inada, Obihiro, Hokkaido 080-8555, Japan
4)Cooperative Department of Veterinary Medicine, Iwate University, 3-18-8, Morioka, Iwate 020-8550, Japan
5)United Graduate School of Veterinary Sciences, Gifu University, 1-1 Yanagido, Gifu 501-1193, Japan
6)Department of Veterinary Theriogenology, Agriculture and Forestry University, Rampur, Chitwan, 44200, Nepal
7)Ichihara Elephant Kingdom Zoological Park, 937, Yamakogawa, Ichihara, Chiba, 290-0521, Japan
8)Department of Veterinary Medicine, Azabu University, 1-17-71, Fuchinobe, Sagamihara, Kanagawa 252-5201, Japan

J. Vet. Med. Sci.
81(6): 857–862, 2019
doi: 10.1292/jvms.18-0757

Received: 21 December 2018
Accepted: 25 March 2019
Published online in J-STAGE: 10 April 2019

ABSTRACT. The aim of this study was to examine the treatment outcomes of tibial fracture using different configurations of transfixation pinning and casting (TPC) in eight cattle. After pins were inserted to stabilize the fracture site, cast material was placed from the level of the stifle to the hoof (full TPC) in six cases and from the stifle to the proximal metatarsus (partial TPC) in two cases. Five cattle (three full TPC and two partial TPC cases) underwent TPC removal 36–86 days after surgery and resumed productivity. The other three cattle which underwent full TPC suffered from irreversible orthopedic complications within 5 weeks of surgery, while a prolonged healing process was observed in the partial TPC cases. Although TPC is an effective method for treating bovine tibial fracture, full TPC may result in a guarded prognosis in some cattle. However, partial TPC can delay healing. Surgeons should choose the optimal TPC configuration while considering the various factors that affect the healing process.

KEY WORDS: cattle, tibial fracture, transfixation pinning and casting (TPC), treatment outcome

Fifty percent of bovine limb fractures occur in the metacarpus and metatarsus and 12 percent occur in the tibia [2]. The primary treatment option for distal limb fractures in cattle is external coaptation [21], which is a non-surgical method for repairing fracture fragments using cast materials. However, tibial fractures more often require surgical repair, as they may not be sufficiently stabilized by cast immobilization [1, 13, 14]. Transfixation pinning and casting (TPC) is an external skeletal fixation (ESF) method that uses transfixation pins proximal and distal to the fracture site and cast materials to encase the affected limb as an external frame [1, 2, 21]. TPC is one of the most widely used methods for repairing tibial fractures in cattle [1, 2]. The advantage of TPC is the minimal distance between the pins and the frame, allowing for more rigid stabilization compared to traditional ESF [1, 21]. St-Jean *et al.* [19] reported favorable outcomes of tibial fracture repair in five calves using TPC constructed with cast materials encircling the limb from the stifle to the metatarsophalangeal joint as an external fixator (partial TPC). Anderson *et al*. [1, 2] suggested that cattle weighing over 150 kg require TPC constructed with a full-limb cast (full TPC) for optimal fracture stability. However, no comparison of TPC configurations with their prognoses has been reported. In the present report, we reviewed our experience with outpatient treatment for tibial fracture using either full or partial TPC in eight cattle weighing 28–250 kg. The aim of this report was to describe the influence of TPC configuration on treatment outcomes of bovine tibial fractures.

Eight cattle were referred to the Veterinary Teaching Hospital of Iwate University (VTH-IU; Case Nos. 1 and 2) or the Veterinary Medical Center of Obihiro University of Agriculture and Veterinary Medicine (VMC-OU; Case Nos. 3–8) for treatment

*Correspondence to: Yamagishi, N.: yamagishi@obihiro.ac.jp

of suspected tibial fractures (Table 1). Of the eight cattle, five (Case Nos. 1–4 and 8) were newborn Japanese Black calves aged 1–5 days (28–37 kg), and the other three (Case Nos. 5–7) were growing Holstein or Japanese Black cattle aged 162–402 days (188–250 kg). Six cattle (Case Nos. 1–6) received first aid treatment with external coaptation from the referring veterinarian 1–5 days before arrival, whereas two cattle (Case Nos. 7 and 8) received no prior treatment. Preoperative radiographs confirmed comminuted distal (Case No. 1) or proximal diaphyseal fractures (Case Nos. 2–4 and 8) or oblique mid-diaphyseal fractures (Case Nos. 5–7) of the tibia. Furthermore, two cattle (Case Nos. 1 and 5) suffered from open fractures classified as type IIIa (fractures associated with extensive soft tissue laceration or flaps with adequate soft tissue coverage of a fractured bone) or type IIIb (fractures associated with extensive soft tissue injury with periosteal stripping and bone exposure) according to the Gustilo and Anderson classification of open fractures scheme [6–8].

Prior to surgery, the cattle were sedated with either 0.1 mg/kg body weight (BW) of xylazine (2% Seractal; Bayer, Tokyo, Japan) (Case Nos. 1–4, 7, and 8) or 20 µg/kg BW of medetomidine (Dorbene; Kyoritsu, Tokyo, Japan) (Case Nos. 5 and 6) intravenously, followed by administration of 10 mg/kg BW of cefazolin sodium (Cefazolin-Chu; Fujita Pharmaceutical, Tokyo, Japan) and 2 mg/kg BW of flunixin meglumine (FORVET-50; Nagase Medicals, Itami, Japan) intravenously before surgery. Sacrococcygeal epidural anesthesia was induced with a 2–5 m*l* lidocaine solution (2% xylocaine; AstraZeneca, Osaka, Japan) (Case Nos. 1–4 and 6–8). A 10 m*l* lidocaine solution (2% xylocaine) was administered to achieve analgesia in four cattle (Case Nos. 5–8) by ultrasound-guided sciatic nerve blockage according to a method reported previously [18]. Two calves (Case Nos. 1 and 2) were positioned in a lateral recumbent position to point the affected limb upward, while the other six (Case Nos. 3–8) were laid in a supine position for upward traction of the affected limb. The fractured limb was clipped and prepared aseptically from the distal femur to the proximal metatarsus. During surgery, additional xylazine (0.05 mg/kg BW) was given intramuscularly in four cattle at 20- to 40-min intervals (Case Nos. 1–4). The other four cattle were intubated shortly after sedation and given 100% oxygen with an inhalation anesthetic machine (Mera; Senko Medical Instrument, Tokyo, Japan). The cattle then received either medetomidine (20 µg/kg BW/hr; Case Nos. 7 and 8) or xylazine (0.2 mg/kg BW/hr; Case Nos. 5 and 6) at a continuous rate of infusion during surgery and temporal isoflurane anesthesia (Isoflu; Zoetis Japan, Tokyo, Japan) during the insertion of pins into the bone.

The fractures were repaired using a closed approach in four cattle (Case Nos. 2–4 and 8) and by open reduction in the other four (Case Nos. 1 and 5–7) (Table 1). In the two cattle (Case Nos. 1 and 5) with open fractures, the fracture site was exposed by skin incision, and contaminated tissues (skin, muscles, and bone) were debrided followed by saline lavage. At each pin insertion site, a small stab incision was performed followed by blunt dissection to the bone. At transfixation pin placement, one to three 3.0- or 4.0-mm smooth pins (code no. 01-063-27 and 01-130-60; Mizuho Ikakogyo, Tokyo, Japan) were inserted percutaneously both proximal and distal to the fracture in all cases. In three cases of closed fractures (Case Nos. 2, 6, and 7), one 3.0- or 4.0-mm smooth pin was inserted percutaneously across the fracture plane to stabilize the fragments (Fig. 1c; arrowhead). In addition, three cattle underwent insertion of a 3.0- or 4.0-mm smooth pin (Case Nos. 6 and 7) or two 1.8-mm smooth pins (Case No. 8; code no. 01-063-24; Mizuho Ikakogyo) from the tibial intercondylar fossa into the intramedullary space to enhance fragment stability (Fig. 2b). In two calves with caudomedial or caudolateral displacements (Case Nos. 1 and 2), two 3.0-mm threaded pins (code no. 01-134-59; Mizuho Ikakogyo) were positioned into the proximal fragment in a "half-pin" configuration to adjust the alignment of the fractured bone (Fig. 1c). After radiographic examination to confirm alignment of the tibia, a cefazolin-containing ointment was applied around each pin site, and the area was covered with sterile gauze. Full TPC was performed in six cattle (Case Nos. 1–6), covering the limb from the level of the stifle to the sole of the hoof (Fig. 1e). Partial TPC was performed in the other two cattle (Case Nos. 7 and 8), encasing the limb between the level of the stifle and the proximal metatarsus (Fig. 2d). A layer of cast padding (Orthowrap 3; Alcare, Tokyo, Japan) was then applied. Next, four to eight layers of fiberglass casting tape (Scotchcast Plus J3; 3M Japan Health Co., Tokyo, Japan) were placed, incorporating the pin ends. The number of layers of tape used depended on the animal's weight [9]. The pins were cut at the level of the cast surface and joined together with epoxy putty (Cemedine Epoxy Putty [for metal]; Cemedine, Tokyo, Japan) or resin (Basing Resin; Yamahachi Dental MFG. Co., Aichi, Japan). In the two cattle with open fractures (Case Nos. 1 and 5), a square-shaped window was created on the top of the wound to facilitate lavage and cleaning after surgery. The surgeries were completed in 80–240 min.

All cattle were returned to their farms on the day of surgery and confined to their individual stalls. Systemic antibiotic therapy was administered by the referring veterinarians for 5–10 days after surgery. The two cattle with open fractures (Case Nos. 1 and 5) underwent lavage of the fracture site at least every 2–3 days. In three of the six animals treated with full TPC (Case Nos. 2–4), the distal region of the cast was truncated below the tarsal joint at 13–18 days after surgery with a mineralized callus formation. The TPC was then removed at our hospital 39–46 days after surgery under sedation with xylazine following radiographic confirmation of bone union (Fig. 1d). In the other three full TPC cases (Case Nos. 1, 5, and 6), either contralateral or ipsilateral coxofemoral luxation or ipsilateral femur physeal fracture developed on the farm within 5 weeks of surgery. The animals were thus euthanized, although callus formation at the fracture site was confirmed radiographically. In one bullock treated with partial TPC (Case No. 7), clinical bone union was apparent 9 weeks after surgery, but TPC removal was delayed until 86 days after surgery (Fig. 2c) because of the owner's difficulty in transporting the animal to our hospital. A severe cast sore in the area from the tuber calcanei to the superficial flexor tendon of the affected limb was found 9 weeks after surgery in this case. The caudal aspect of the cast was thus partially trimmed, and the site of ulceration was bandaged until TPC removal. In another calf treated with partial TPC (Case No. 8), the TPC was removed at 36 days after surgery under sedation after radiographic detection of bone union. In this case, pin tract infection was identified by serous discharge at the time of TPC removal but was resolved by 60 days after surgery through continued use of systemic antibiotics and cleaning with sterile saline. All five animals remained healthy without chronic infection or refracture after TPC removal. They grew normally and were later sold at a cattle market (Case Nos. 2–4 and 8) or reared on the

Table 1. Clinical information of eight cattle with tibial fractures treated by transfixation pinning and casting (TPC)

Case No.	Breed (sex)	Age in days (body weight, kg) on the day of surgery	Duration (days) before visit for surgery	Type of fractures and preoperative radiography	Surgery (reduction, configurations of TPC)	Number of pins for TPC (and IP)	Duration of surgery (min)	Post-surgical removal of TPC (days)	Outcome
1	JB (Female)	2 (28)	2	Open (IIIa)[a], comminuted distal diaphyseal fracture with caudomedial displacement and mild proximal overriding in right tibia	Open, Full-TPC	6	80	–	Contralateral coxofemoral luxation (17 days post-surgery)
2	JB (Female)	5 (34)	5	Closed, comminuted proximal diaphyseal fracture with caudolateral displacement and proximal overriding in left tibia	Closed, Full-TPC	7	90	39	Good, sold at a cattle market
3	JB (Male)	3 (35)	2	Closed, comminuted proximal diaphyseal fracture with craniolateral displacement and mild proximal overriding in left tibia	Closed, Full-TPC	5	100	46	Good, sold at a cattle market
4	JB (Male)	5 (37)	5	Closed, comminuted proximal diaphyseal fracture with caudomedial displacement and proximal overriding in left tibia	Closed, Full-TPC	4	110	41	Good, sold at a cattle market
5	HF (Female)	402 (250)	1	Open (IIIb)[a], mid-diaphyseal oblique fracture with caudolateral displacement and proximal overriding in right tibia	Open, Full-TPC	5	220	–	Ipsilateral femur epiphyseal fracture (Salter-Harris type I) (33 days post-surgery)
6	HF (Female)	162 (188)	2	Closed, mid-diaphyseal oblique fracture with craniolateral displacement and proximal overriding in right tibia	Open, Full-TPC with IP	7 (1)	240	–	Ipsilateral coxofemoral luxation (15 days post-surgery)
7	JB (Castrated male)	203 (246)	1	Closed, mid-diaphyseal oblique fracture with craniolateral displacement and proximal overriding in left tibia	Open, Partial-TPC with IP	7 (1)	180	86	Good, still fed at the farm
8	JB (Female)	1 (31)	1	Closed, comminuted proximal diaphyseal fracture with craniolateral displacement and proximal overriding in left tibia	Closed, Partial-TPC with IP	4 (2)	85	36	Good, sold at a cattle market

JB: Japanese Black, HF: Holstein Friesian, IP: intramedullary pin placement. a) IIIa or IIIb: Gaustilo and Anderson classification of open fractures.

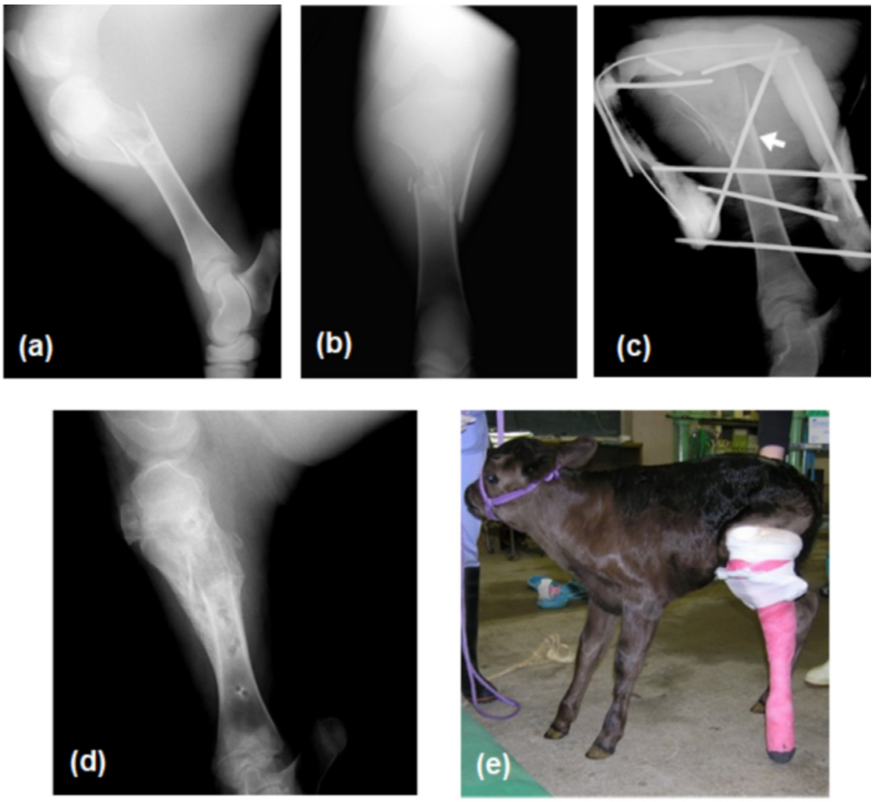

Fig. 1. Radiographs of the tibia (a, b, c and d) and photograph (e) of Case No. 2 (a 5-day-old calf weighing 34 kg) treated with full transfixation of pinning and casting (TPC). Lateral and cranial views of left comminuted tibial fracture (a, b) before and (c) after surgery (arrowhead; the pin inserted through fracture plane), and (d) at 39 days post-surgery (TPC removal). (e) Full TPC encasing the limb from the level of the stifle to the sole of the hoof.

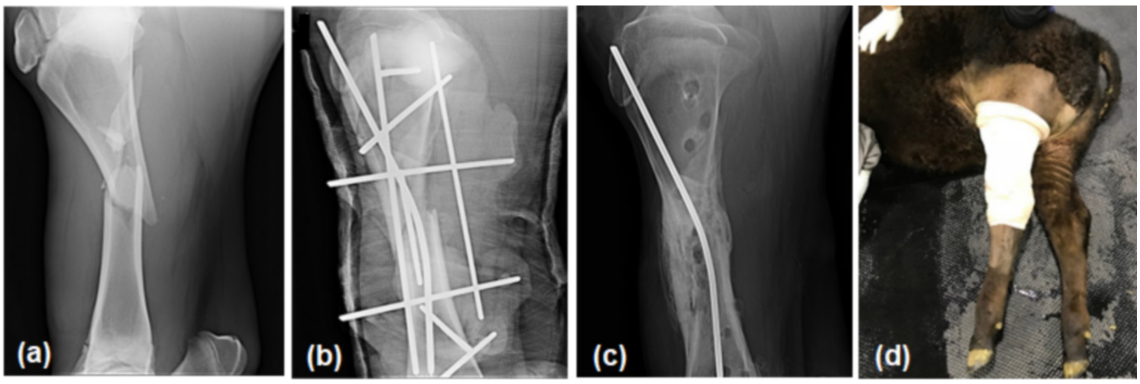

Fig. 2. Radiographs of the tibia (a, b, and c) and photograph (d) of Case No. 7 (a 203-day-old bullock weighing 246 kg) treated with partial transfixation of pinning and casting (TPC). Lateral view of left tibia (a) before and (b) after surgery and (c) at 86 days post-surgery (TPC removal). (d) Partial TPC encasing the limb between the level of the stifle and the proximal metatarsus.

same farm (Case No. 7). In Case No. 2, subtle lameness was recognized at the calf market.

The tibia is one of the most common bone fracture sites in cattle [2, 5, 13]. With the exception of neonatal tibial fracture, which can be wrapped around the stifle, the proximal joint of the tibia and radius is difficult to immobilize because the fracture site remains mobile [1, 13, 14]. While external coaptation is the most feasible treatment for fractures in farm animals, it is difficult to treat open and comminuted fractures [1, 14]. ESF treatment can provide stability for bone segments by allowing loading force transmission through the fixator [3, 14, 17, 21]. The biomechanical force on the fracture plane increases in proportion to BW;

therefore, full TPC is recommended for animals weighing over 150 kg, as it reduces axial compression and bending and torsional force in bone fragments [1–3, 21]. However, based on our clinical experience, full TPC may predispose some cattle to the irreparable damage associated with constantly wearing a full-limb cast.

In this report, two growing heifers with full TPC suffered from ipsilateral femur physeal fracture (Case No. 5) or coxofemoral luxation (Case No. 6) within 5 weeks of surgery. Transarticular casting causes potential damage to the involved joint [1]. Ideally, casting should be performed in the normal weight-bearing position to prevent diminished use of the affected limbs [19]. However, it is difficult to maintain such a position while fixing the alignment of the displaced bone segments, especially in heavy cattle. We previously reported successful full TPC treatment in a 300-kg heifer with a closed tibial fracture [10]. In that case, the heifer was fortunately able to adapt to the transarticular casting, although all of the 2.5-mm Kirchner wires were bent due to the loading force [10]. Excessive weight-bearing should thus be expected, especially in heavy cattle weighing over 150 kg, as the limited motion of limbs in full-limb casting may give rise to catastrophic damage to the hind limbs.

After the failure of full TPC treatment in heavy cattle (Case Nos. 5 and 6), we performed partial TPC in a 246-kg bullock with a combination of intramedullary pinning (Case No. 7), a technique that is most often utilized in cattle weighing less than 100 kg [21]. ESF and TPC enable the early recovery of function in the affected limb by increasing interfragmentary motion in the bone and weight-bearing capacity, which promote callus formation [12, 17, 21]. These methods enable clinical union in 4–6 weeks in calves with bone fractures [1]. In our four newborn calves treated with full or partial TPC which resulted in clinical recovery (Case Nos. 2–4 and 8), the TPCs were removed at 5–6.5 weeks after surgery, with sufficient bone union observed. Contrarily, a 246-kg bullock treated with partial TPC (Case No. 7) did not show sufficient bone union until 9 weeks after surgery. Excess motion of the bone fragments was inextricably associated with pain and delayed healing [1, 12]. Instability of the fragments caused by a lack of rigidity in partial TPC against the bullock's substantial weight load was related to delayed healing at fracture sites. Moreover, fracture repair by open reduction may result in delayed healing compared with repair by closed reduction [22]. We therefore speculated that the prolonged healing process in this bullock resulted in its reluctance to use its limbs and consequently facilitated successful bone union supported by the intramedullary pin.

Open fractures contaminated with dirt are difficult to treat and often result in a poor prognosis [2, 5, 14]. In such cases, TPC is preferred over cast immobilization because it allows direct wound access by fenestration and enables early recovery by conserving local blood flow, providing cytokines and growth factors for wound healing [1, 14]. In general, clinical union of an open fracture with severe soft tissue damage usually requires 12 weeks or more in cattle [1, 2]. We previously experienced delayed union of a tibial open fracture (type IIIb) in a 47-kg neonatal calf [11] showing a valgus deformity (angulated 30°) after 16 weeks of convalescence. However, the present cases with type III open fractures (Case Nos. 1 and 5) developed either contralateral coxofemoral luxation or ipsilateral femoral physeal fractures before wound closure. These cattle remained recumbent after injury and required assistance in standing up during convalescence. While standing up, difficulty in using the affected limb caused by the lack of joint mobility associated with a full-limb cast resulted in fatal damage to the opposite or adjacent part of limb. A prolonged and guarded prognosis of severe type III open fractures should be anticipated in full TPC repair.

Correct anatomical alignment and rigid stability is the primary goal of internal fixation [15, 16]. Direct compression plates provide more fracture stability against high loading forces [15, 20]. The application of a locking compression plate increases the holding power of the screws in thin cortices of neonatal long bones, avoiding plate loosening [15, 16, 21]. In Japan, however, bovine orthopedic treatment is sometimes conducted by general practitioners without anesthetists, and post-surgical care on the farm is more common. The TPC method is performed less invasively using closed reduction, which allows for shorter surgical time under local anesthesia with sedation [15, 22]. Moreover, reduced surgical intervention facilitates early recovery of limb function with less soft tissue damage and loss of neurovascular supply, enabling cattle to return to the farm on the day of surgery [2, 22]. Poor anatomical fixation by TPC sometimes results in limb shortening or angulation [11, 14], but concomitant use of half-pins and intramedullary pins can effectively prevent malunion. Bone remodeling corrects mild deformities by replacing hard callus with lamellar bone, which usually enables cattle to return to productivity [4, 12]. In conclusion, the present retrospective study suggests that TPC configuration indeed influenced treatment outcomes. Full TPC reduction may pose the risk of secondary complications, while partial TPC reduction gives rise to delayed bone union accompanied by a lack of stability. Surgeons should keep the drawbacks of TPC reduction in mind to achieve successful tibial fracture treatment in cattle.

ACKNOWLEDGMENTS. We are grateful to all referring veterinarians and the staff members of the VTH-IU and VMC-OU for their support.

REFERENCES

1. Anderson, D. E. and St Jean, G. 1996. External skeletal fixation in ruminants. *Vet. Clin. North Am. Food Anim. Pract.* **12**: 117–152. [Medline] [CrossRef]
2. Anderson, D. E. and St Jean, G. 2008. Management of fractures in field settings. *Vet. Clin. North Am. Food Anim. Pract.* **24**: 567–582, viii. [Medline] [CrossRef]
3. Baxter, G. M. and Wallace, C. E. 1991. Modified transfixation pinning of compound radius and ulna fracture in a heifer. *J. Am. Vet. Med. Assoc.* **198**: 665–668. [Medline]
4. Frost, H. M. 1994. Wolff's Law and bone's structural adaptations to mechanical usage: an overview for clinicians. *Angle Orthod.* **64**: 175–188. [Medline]
5. Gangl, M., Grulke, S., Serteyn, D. and Touati, K. 2006. Retrospective study of 99 cases of bone fractures in cattle treated by external coaptation or

confinement. *Vet. Rec.* **158**: 264–268. [Medline] [CrossRef]
6. Gustilo, R. B. and Anderson, J. T. 1976. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J. Bone Joint Surg. Am.* **58**: 453–458. [Medline] [CrossRef]
7. Gustilo, R. B., Mendoza, R. M. and Williams, D. N. 1984. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J. Trauma* **24**: 742–746. [Medline] [CrossRef]
8. Gustilo, R. B., Simpson, L., Nixon, R., Ruiz, A. and Indeck, W. 1969. Analysis of 511 open fractures. *Clin. Orthop. Relat. Res.* **66**: 148–154. [Medline] [CrossRef]
9. Hara, S., Kawamoto, Y., Nuta, S. and Tomizawa, N. 1996. Mechanical strength of synthetic casting tape for application to fracture treatment of farm animals. *Vet. Comp. Orthop. Traumatol.* **9**: 79–83. [CrossRef]
10. Ikegaya, A., Ogasawara, Y., Ikeda, A., Miura, M., Anan, T., Takehana, K., Yamaguchi, E., Kim, D., Sato, S. and Yamagishi, N. 2009. Tibial bone fracture in an 11-month-old Japanese-black calf. *Jpn. J. Vet. Clinics* **32**: 18–21 (in Japanese with English abstract). [CrossRef]
11. Itagaki, K., Kim, D., Sasaki, K., Devkota, B. and Yamagishi, N. 2011. Clinical characteristics of limb fractures in 25 calves and growing cattle. *Jpn. J. Large Anim. Clin.* **2**: 197–204 (in Japanese with English abstract). [CrossRef]
12. Marsell, R. and Einhorn, T. A. 2011. The biology of fracture healing. *Injury* **42**: 551–555. [Medline] [CrossRef]
13. Martens, A., Steenhaut, M., Gasthuys, F., De Cupere, C., De Moor, A. and Verschooten, F. 1998. Conservative and surgical treatment of tibial fractures in cattle. *Vet. Rec.* **143**: 12–16. [Medline] [CrossRef]
14. Mulon, P.Y. 2013. Management of long bone fractures in cattle. *In Pract.* **35**: 265–271. [CrossRef]
15. Nuss, K. 2014. Plates, pins, and interlocking nails. *Vet. Clin. North Am. Food Anim. Pract.* **30**: 91–126, vi. [Medline] [CrossRef]
16. Nuss, K., Spiess, A., Feist, M. and Köstlin, R. 2011. [Treatment of long bone fractures in 125 newborn calves. A retrospective study]. *Tierarztl. Prax. Ausg. G Grosstiere Nutztiere* **39**: 15–26 (in German with English abstract). [Medline]
17. Palmer, R. H., Hulse, D. A., Hyman, W. A. and Palmer, D. R. 1992. Principles of bone healing and biomechanics of external skeletal fixation. *Vet. Clin. North Am. Small Anim. Pract.* **22**: 45–68. [Medline] [CrossRef]
18. Re, M., Blanco-Murcia, J., Villaescusa Fernández, A., De Gaspar Simón, I. and Gómez de Segura, I. A. 2014. Ultrasound-guided anaesthetic blockade of the pelvic limb in calves. *Vet. J.* **200**: 434–439. [Medline] [CrossRef]
19. St-Jean, G., Clem, M. F. and DeBowes, R. M. 1991. Transfixation pinning and casting of tibial fractures in calves: five cases (1985–1989). *J. Am. Vet. Med. Assoc.* **198**: 139–143. [Medline]
20. Verschooten, F., De Moor, A., Desmet, P. and Steenhaut, M. 1972. Surgical treatment of tibial fractures in cattle. *Vet. Rec.* **90**: 24–28. [Medline] [CrossRef]
21. Vogel, S. R. and Anderson, D. E. 2014. External skeletal fixation of fractures in cattle. *Vet. Clin. North Am. Food Anim. Pract.* **30**: 127–142, vi. [Medline] [CrossRef]
22. Yamagishi, N., Devkota, B. and Takahashi, M. 2014. Outpatient treatment for humeral fractures in five calves. *J. Vet. Med. Sci.* **76**: 1519–1522. [Medline] [CrossRef]