Research Article

The treatment of distal metacarpus fracture with locking compression plate in calves*

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Abstract: In this study, we aimed to evaluate the effect of locking compression plates for the treatment of distal metacarpal fractures in calves. The metacarpus was stabilized using a stainless steel locking compression plate with fully threaded locking head screws. The calves started weight-bearing partially after the first postoperative day and resumed complete weight-bearing after day 10. Callus formation was obtained at the end of the 3rd week and completed at the end of the 8th week, and complete healing was seen at the 12th week in radiographs. The limbs were in good alignment, the calves were fully weight-bearing, and client satisfaction was very high. The metacarpal length, diameter of cortex, and diameter of medulla were measured in fractured and nonfractured metacarpi at the 1st, 45th, 120th, and 365th postoperative days. In conclusion, as the characteristics of juvenile bones do not provide sufficient physical strength for implants, we decided that locking compression plates are associated with good prognosis for surgical repair of distal metacarpal fractures in newborn calves.

Key words: Calf, metacarpus, fracture, locking compression plate

1. Introduction

Metacarpal fractures rank first in order of frequency of long-bone fractures in calves. The most common cause of metacarpal fractures in calves is excessive traction during delivery. Excessive traction on the forelimbs of a calf in anterior presentation may result in metacarpal fractures if a lever action is applied to the forelimbs (1). Trauma due to falling on a concrete floor or hitting other animals or moving objects are some other causes (1,2) that may lead to metacarpal fractures.

Ferguson (2) reported that the 50% of fracture cases seen in cattle are metacarpus and metatarsus fractures. Köstlin et al. (3) stated that metacarpus fractures, with an incidence rate of 40.5%, are the most common fractures among the extremity fractures seen among cattle. Görgül et al. (4) categorized the different types and locations of 31 fractures; 25% fractures occurred during forced extraction at birth and 12.1% were due to trauma. In another study of newborn calves, all of 33 metacarpal fractures resulted from forced extraction during delivery and were located in the distal diaphysis-metaphysis (5). Elma (6) reported 42 diaphysis fractures, 20 metaphysis fractures, and 4 distal epiphyseal separations in 69 metacarpal fractures in calves.

In calves, metacarpal fractures occur most often in the distal epiphysis and metaphysis (5,7). Type I Salter–Harris fracture of the distal epiphysis and metaphysis are common fractures in cattle. In a study of newborn calves, 12 of 33 metacarpal fractures (36.4%) were located in the distal metaphysis. Because the cortex becomes considerably thinner at the transition from diaphysis to metaphysis, this part of the metacarpus has only limited axial strength (1). Elma (6) evaluated a total of 69 metacarpus fractures radiologically and reported that there were diaphyseal fractures in 42 cases, metaphyseal fractures in 20 cases, distal epiphyseal separation in 4 cases, and epiphyseal separation together with metaphysis fracture (Salter–Harris type 2) in 3 cases. Most metacarpal fractures in newborn calves are comminuted transverse fractures (2,8).

Conservative and surgical treatment options for bovine long-bone fractures, most frequently metacarpal fractures, have been described predominantly in calves and young cattle. Metacarpal fracture immobilization has been achieved most commonly with external cooptation (casts or Schroeder–Thomas splints), transfixation pins with or without application of casts, or internal fixation (usually plates and screws) (2,9,10).

The softness of the metacarpal bone is one of the major concerns for plate osteosynthesis in neonatal calves (1,11). Soft neonatal bone can predispose to loosening of the screws and subsequent instability of the fixation.

The purpose of our study was to evaluate the efficiency of locking compression plates (LCPs) in preventing these predisposing factors in the treatment of metacarpal fractures in newborn calves.

2. Materials and methods

2.1. Preoperative procedures

Twenty calves of different breeds, ages, and sexes with distal metacarpal fractures admitted to the teaching hospital were included in this study. By means of anamnesis, the breed, age, weight, sex, birth, type of fracture, and duration between the injury and presentation to the veterinary hospital were recorded. Clinical examination was made. Radiographs in dorsopalmar and lateromedial projections were taken. The shape of the fracture, degree of comminution, and degree of displacement were evaluated on radiographs (Figures 1a and 1b). Measurements for plate and screw lengths were performed. A full-limb cast was applied until the time of surgery. Animals were fasted for 12 h before the surgery. Parenteral antibiotic administration (amoxicillin-clavulanic acid, Synulox, Pfizer, 9 mg/kg IM) was started before the operation

Figure 1. Dorsopalmar (a) and mediolateral (b) radiographic view of the metacarpus of 1-day-old calf showing transversal fracture with several fragments.

and continued for 10 days postoperatively. During the operation, vascular access was maintained and lactated ringer solution was applied through intravenous infusion. The operation room was disinfected with a UV lamp the day before the operation.

2.2. Surgical technique

The calves were placed in lateral recumbency with the affected limb upward. General anesthesia including a solution of xylazine hydrochloride (Alfazine, Egevet, 0.2 mg/kg IM) and ketamine hydrochloride (Alfamine, Egevet, 2.2 mg/kg IM), with 3% inhalation of isoflurane gas (Forane, Abbott; vaporized in 100% oxygen), was administered via a semiclosed rebreathing system. The leg was clipped and aseptically prepared for surgery. Part of the affected limb above the hoof and carpal joint was covered with sterilized gauze. The animal's body was covered with sterilized covers, except at the operation area.

The line of fracture was approached by a curvilinear S-type skin incision on the dorsal surface of the metacarpus. The fractured area was reached by blunt dissection of subcutaneous tissues. The limb was aligned and the fractured bone was positioned. The metacarpus was stabilized using a stainless steel LCP (2 mm thickness, 20 mm width, and 90–110 mm length) with fully threaded locking cortical screws (3.5 Ø, 30–35 mm length, cancellous for distal fragment; 3.5 Ø, 26–32 mm length, cortical for proximal fragment). The plates were contoured to the cranial/dorsal surface of the bones. The shape of the LCP was designed as the letter T. The overhead of the plate (2 mm thickness, 3 width, and 2 mm length) had 3 holes. The shaft of the plate had 6–8 holes and both overhead and shaft holes were aligned cross-sequentially. All edges of the plate were rolled. In some cases, a spongiosis screw was applied because of the weakness of the compact bone. The region was rinsed with normal saline and was checked for hemorrhage. Subcutaneous tissues were closed in simple continuous sutures with polyglactin 910 (Vicryl Ethicon-USP 1-2), the skin was closed with simple interrupted sutures using silk (Silk Kruuse-USP 1-2), and the operation process was completed (Figures 2a–2c). X-ray images were taken for postoperative control.

2.3. Postoperative procedures

After surgery, calves were confined to a calf hutch. For the purpose of preventing possible infections, antibiotics (amoxicillin-clavulanic acid, Synulox, Pfizer, 9 mg/kg IM, daily for 10 days) and a nonsteroidal antiinflammatory drug (flunixin meglumine, Fynadin, Intervet, 2.2 mg/kg IM, daily for 5 days) were administered in all cases in the postoperative period. The operation wound was protected under medical dressing. The relevant leg was supported by a synthetic acrylic plaster bandage for 10 days. In this period, calves were kept under control. After about 10 days, the bandage and sutures on the skin were removed.
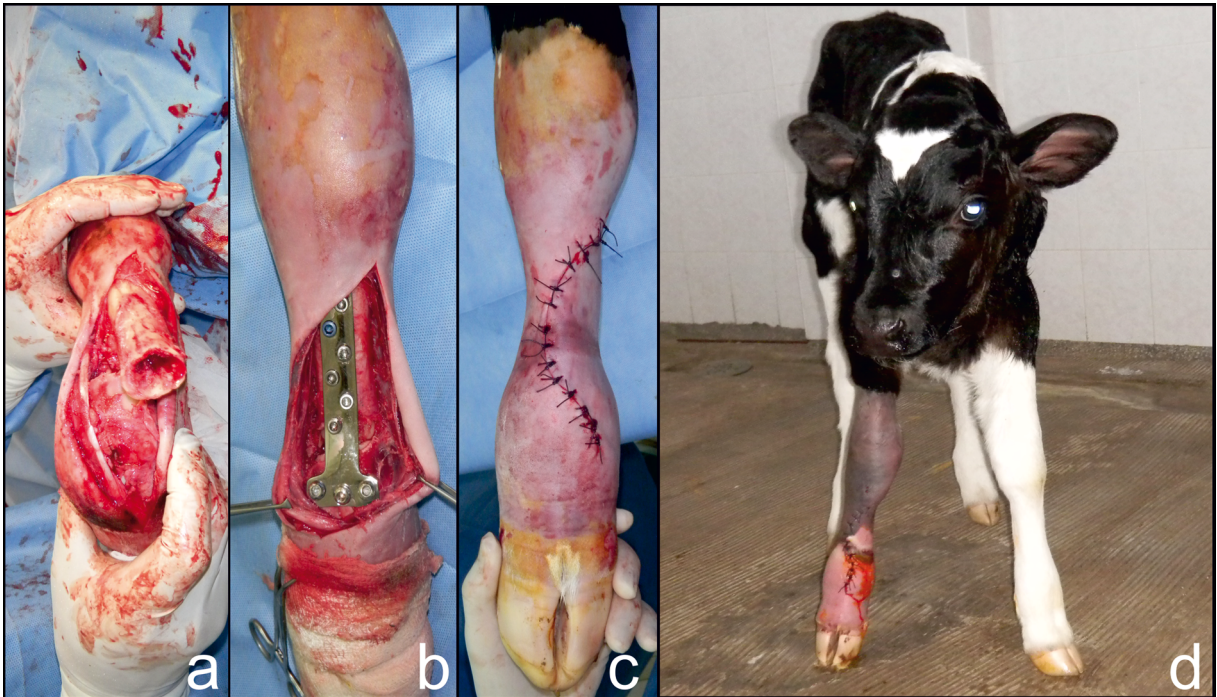
Figure 2. (a–c) These pictures show adequate reduction and alignment of bone fragments immediately after application of the LCP. (d) General view of calf 1 day after surgery, with immediate weight-bearing with affected forelimb after stabilizing with LCP.

Clinical and radiological follow-up of the cases was done shortly after the removal of the bandage and at days 15, 30, 45, 60, and 120. The metacarpal length, diameter of cortex, and diameter of medulla were measured at postoperative days 1, 45, 120, and 365 on radiographs. Measurements of wrist and foot axis were calculated at the end of 1 year. Weight-bearing, pain, and status of the implant were followed carefully. On postoperative days 15, 30, 45, 60, and 120, calves were examined in the light of clinical and radiological findings by comparison with the healthy limb in terms of shortening in the metacarpus, atrophy in regional muscles, dorsal slope, and heel joint angles for possible changes.

2.4. Statistical analysis
To determine the normal distribution of data the Shapiro–Wilk test was applied, and the homogeneity of variances was evaluated by means of the Levene test. Logarithmic transformation was applied to data exhibiting abnormal distribution. To consider the interaction of time and group factors, two-way analysis of variance was used with repeating measurements. P < 0.05 was considered significant.

3. Results
Twenty calves (17 Holstein, 2 Simmental, and 1 crossbreed) with surgically repaired distal metacarpal fractures were identified. There were 12 males and 8 females, of ages ranging from 1 to 5 days and body weights ranging from 35 to 50 kg. Out of these fractures, 13 were on the left limb and 7 were on the right limb.

All fractures had occurred due to excessive force during birth assistance. When the calves were brought to the clinic, they could not stand up. The calves were admitted to the clinic at different times ranging from the first couple of hours to 1 week postcalving. In some cases, there were residuals of maternal tissues. All of the fracture cases brought to the clinic were closed fractures. In the clinical examination, location of fracture, pain, crepitus, deformation of the metacarpus, abnormal movement, and length/shortening of the affected limb were determined. Furthermore, in light-colored calves, subcutaneous hemorrhages due to the pressure of the birth chain/rope were evident. The skin was usually uninjured. All calves had elevated heart and respiratory rates at the time of admission. According to X-ray images the lines of fractures were transversal and comminuted. It was observed that almost all of the metacarpus bones were in fragmentized fracture form in the two-direction X-ray images taken during radiological examination. Most of the bone fragments were displaced.

The fracture region was easily accessed. Bone fractures were multifragmented (in small fragments). As it was not possible to integrate these parts, they were removed from the area. Considering the sulcus longitudinalis dorsalis located at the dorsal medial line of the metacarpus, fractured fragments were positioned properly. Adequate

fracture reduction and stabilization was achieved during surgery. One metacarpus was assigned to secure a 20-mm-broad LCP with 6–8 roughened locking cortical screws (3.5 Ø, 26–32 mm) on the proximal diaphysis and 3 cancellous screws on the distal diaphysis. Spongiform screws were used on the distal fragment (3.5 Ø, 30–35 mm). General anesthesia lasted 70 min approximately and uneventful recovery occurred.

The following day, calves were examined in the calf hutch. Nutrition was normal. There was no abnormality in general health status, and most of them were standing. They were able to stand on the affected limb (Figure 2d). Due to the calves being newborn and the weak anatomical structure of the bone, and also the importance (critical period) of postoperative days 7–10 for fracture healing, an acrylic bandage was applied for 10 days. At the end of this period, calves started to use the treated limb remarkably. Within the following month, weight-bearing developed considerably. On day 45, standing and walking were almost normal.

As a result of pressure on the skin caused by the calving rope/chain, injuries were observed in 4 cases. They were taken under control with wound treatment. Nevertheless, infection due to injury and a fracture caused by another trauma at the 6th postoperative week could not be treated in one case. This calf was discharged with a recommendation for slaughter because of continued severe lameness and infection. There was no evidence of malpositioning of implants on radiographs postoperatively. During the first 2 weeks, no significant progress was seen in callus production (Figure 3a). During the 3rd week, there was poor callus formation along fracture gaps and it became evident at the 4th week (Figure 3b); it was then observed on the radiographs taken at the 8th week that consolidation was completed. At the 12th week, there was dense callus formation along the fracture gaps (Figure 3c). A significant density loss was not seen in the postoperative period. Callus development in calves displayed differences. Regarding callus formation, no findings were found in radiographs until 2 weeks after the operation. Despite the fibrocartilage calli that were determined in some cases on radiographs in the 3rd week, radiodense calli were remarkable in the 4th week. Calves were able to clinically stand at this stage. After 5 weeks, obvious callus formation and cooptation were clear on X-ray images, and callus development was completed at the 9th and 10th weeks.

The average metacarpal length, diameter of cortex, and diameter of medulla in the fractured metacarpus were respectively measured at postoperative days 1, 45, 120, and 365 as 163 ± 1.98 mm, 22.57 ± 0.50 mm, and 15.91 ± 0.31 mm; 163 ± 2.26 mm, 26.39 ± 0.55 mm, and 16.56 ± 0.31 mm; 182 ± 1.80 mm, 30.21 ± 0.46 mm, and 17.29 ± 0.31
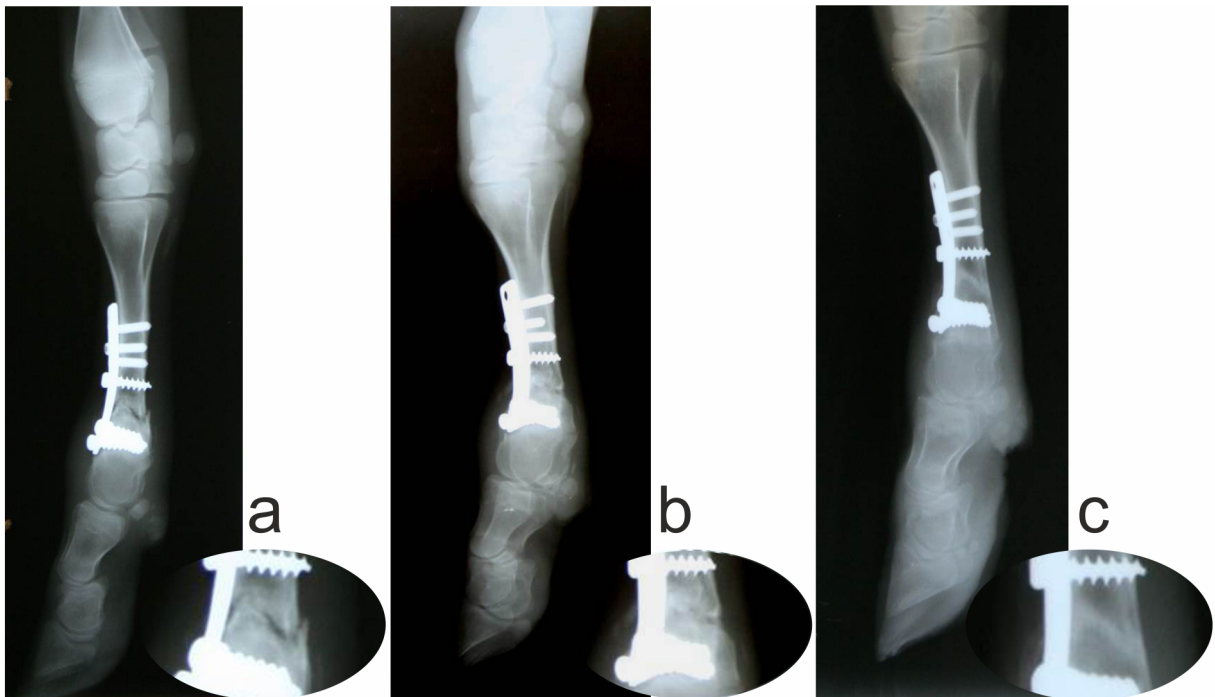

Figure 3. (a) Mediolateral radiographic view of the metacarpus at the end of the 1st week; no significant progress was seen in callus production. (b) Mediolateral radiographic view of the metacarpus at the end of the 4th week; there was poor callus formation along fracture gaps. (c) Mediolateral radiographic projections showing fracture site bridging with periosteal callus at the end of the 12 week.

mm; and 199 ± 1.62 mm 34.53 ± 0.50 mm, and 18.08 ± 0.26 mm. The average metacarpal length, diameter of cortex, and diameter of medulla in the nonfractured metacarpus were respectively measured at postoperative days 1, 45, 120, and 365 as 167 ± 1.81 mm, 22.54 ± 0.50 mm, and 15.96 ± 0.31 mm; 174 ± 1.75 mm, 26.81 ± 0.52 mm, and 17.44 ± 0.31 mm; 195 ± 1.70 mm, 30.57 ± 0.43 mm, and 17.62 ± 0.31 mm; and 207 ± 1.56 mm, 35.68 ± 1.03 mm, and 18.25 ± 0.27 (Tables 1–3). The measurements of wrist and foot axis were calculated as 149.3° and 152.5° in fractured and nonfractured limbs (n = 6), respectively, after 1 year.

In statistical analysis, regarding the difference between metacarpus length and the diameter of the medulla (endosteal diameter), significant difference was found between day 1 values and the values measured at days 45, 120, and 365 among healthy and treated metacarpus bones. A significant difference between groups (between healthy and affected metacarpi) was found only in the metacarpus lengths measured on days 120 and 365. All fractures had occurred due to forced extraction during dystocia and were closed, comminuted, and located in the distal diaphysis.

4. Discussion

The percentage of metacarpus fractures has been progressively increasing due to the disproportionate application of extraction force during calving assistance (4,12,13). Firet (5) reported that among 38 fracture cases that occurred during the calving process, 33 were metacarpal fractures. Görgül et al. (4) indicated that 21 of a total 31 fracture cases were metacarpal. Aksoy et al. (13) reported that 6 of 20 fracture cases were metacarpal. Young calves and bulls in group housing seem to be most commonly affected (1–5). In our study, all metacarpal fractures had occurred during the calving process. Usually in dystocia cases the breeders intervene themselves first and then invite a veterinarian for birth assistance or cesarean operation.

Metacarpal fractures are the most common fractures in cattle of all ages (9). These fractures are frequently comminuted and, because of the limited soft tissue supporting the structures covering the bone, open fractures are common (1–4,8,9,14). In consideration of the local anatomy, open-type fractures are highly possible. There is no strong muscle tissue and bones are surrounded by fibrous tissue. In our study, a compression-type fracture had occurred because of the circular pressure on bone by a chain or rope and all of fractures were surprisingly closed. Despite the anatomical disadvantages, the low possibility of open fracture can be explained in this way. Very small penetrations were observed during the clinical examination caused by the sharp ends of the bone fractures during the transfer of animals. Of these, the calves admitted to the clinic and treated within the first 8 h of the postcalving period were considered to have closed-type fractures in terms of infection risk.

Table 1. The statistical evaluation of metacarpal length (mm) of groups.

Groups	Day 1	Day 45	Day 120	Day 365
Control (n: 20)	167 ± 1.81	174 ± 1.75*	195 ± 1.70*	207 ± 1.56*
Treated (n: 20)	163 ± 1.98	163 ± 2.26*,#	182 ± 1.80*,#	199 ± 1.62*,#

Table 2. The statistical evaluation of cortex thickness (mm) of groups.

Groups	Day 1	Day 45	Day 120	Day 365
Control (n: 20)	22.54 ± 0.50	26.81 ± 0.52	30.57 ± 0.43	35.68 ± 1.03
Treated (n: 20)	22.57 ± 0.50	26.39 ± 0.55	30.21 ± 0.46	34.53 ± 0.50

Table 3. The statistical evaluation of medullar diameter (mm) of groups.

Groups	Day 1	Day 45	Day 120	Day 365
Control (n: 20)	15.96 ± 0.31	17.44 ± 0.32*	17.62 ± 0.31*	18.25 ± 0.27*
Treated (n: 20)	15.91 ± 0.31	16.56 ± 0.31*,#	17.29 ± 0.31*,#	18.08 ± 0.26*,#

*: Statistical difference ($P < 0.05$) according to the 1st day in the same group; #: statistical difference ($P < 0.05$) according to the control group. Values show mean and standard error.

Elma (6) remarked that the fractures observed in cattle were mostly seen in the form of epiphysis separation and affecting epiphysis growth plate in young cattle, and in the form of diaphysis fractures in adult cattle. He also reported 42 diaphysis fractures, 20 metaphysis fractures, 4 distal epiphysis separations, and 3 epiphysis separations together with metaphysis partial fracture (Salter–Harris type 2) in 69 metacarpus fractures. Tulleners (1) reported that 12 of 33 metacarpus metatarsus fractures were observed in the epiphysis region and 21 were in the nonphyseal region, while 23 were closed fractures and 10 were open fractures. Aksoy et al. (13) reported that all of the metacarpus fractures were closed-type fractures and in oblique form in the distal diaphyseal region. In our study, all of the metacarpus fractures occurred around the same location, between the distal diaphysis and metaphysis, and growth plates were not affected. These findings were consistent with 21 fractures in the nonphyseal region (1), with the distal diaphysis (13), and with 62 fractures in the diaphysis-metaphysis region (6).

Successful treatment of long-bone fractures in large animals is a challenging problem (10). Many obstacles are reported associated with fracture repair as well as fracture healing. Successful repair depends upon implants, correct surgical technique, and the skill of contouring the implants to the shape of the bone (15). Unfortunately, many available implants do not meet the requirements for stability, size, shape, versatility, and contourability needed for the repair of certain types of long-bone fractures in large animals. Fixation with dynamic compression plates is currently advocated for internal repair of most long-bone fractures in horses and cattle (16–19).

Since calves were admitted to the clinic in a short time after trauma, the necessary intervention was done immediately against the possibility of open-type fractures in the calves. The possibility of turning into an open-type fracture was reduced both by the uncompleted compact structure of the bone and the compression type of the fracture. The edges of fractures were at the border between the distal diaphysis and metaphysis in almost all cases. In extremity fractures seen in calves, the success rate of the operation in the proximal part of joints is decreased, which increases the chances of the location to go toward the distal section.

Steiner et al. (20,21) suggested treatment according to the configuration of the fracture, i.e. closed or open reduction with an external fixation application to all extremities, or open reduction with plate application for nondisplaced simple fractures. They stated that while fractures with a tendency of displacement and of causing further injuries to the skin (multifragmented fractures with spiral, oblique, and butterfly forms) can be treated with open reduction and plate application, serious multifragmented and complex fractures can be treated

with a walking-cast dressing. Patel et al. (22) and Tyagi and Gill (23) reported that open reduction allows a superior aesthetical view in the region, and fragments of the fracture exhibit better order and reduction. In our study, the formation of the fracture was fragmented and compression fractures. In the meantime, circular ecchymosis areas were evident on the soft tissue as a result of the pressure of the calving chain/rope. Based on its appearance, it could be classified as compression injury and fracture. As a treatment approach, open reduction was applied. Since the injuries were newly formed, the repositioning of the fragments was easy. No intervention was required to give additional positioning during placement of the plate on the bone. Denny et al. (24) treated 31 of 59 fracture cases with surgical interventions, 14 cases with external fixation, and 6 cases with stable rest. Eight of the cattle were transferred to a slaughterhouse without surgical intervention. The 90% success level of the cases treated surgically was concluded as more advantageous when compared with the 57% success level of the cases treated externally. Tulleners (1) stated that when either external or internal fixation or both of them are applied, successful treatment can be obtained. It was claimed that rigid internal fixation with Association for the Study of Internal Fixation plates is more advantageous on fractures of long bones. It was also reported that animals recovered to stand on their legs in a short period of time postoperatively; they required limited care in the short recovery period.

A T-shaped LCP, specially designed for this study, was used in treatment. There were three screw holes at the top of the plate and 6–8 holes on the body. The top part was attached to the distal condyles of the metacarpus by means of spongiosis screws (3.5 mm Ø; 30–35 mm); the body was attached to the diaphysis of the metacarpus by means of fully threaded cortical screws (3.5 mm Ø; 26–32 mm).

Uhthoff et al. (25) emphasized that essential advantages of dynamic compression plates lead to low malunion incidence. They provided stable internal fixation, which does not require external immobilization. This situation provided early motility of adjacent joints. Patel et al. (22) declared that partial weight-bearing with support of a bandage started on the day after the operation; however, full weight-bearing was seen between days 26 and 32 in 3 tibia fracture cases that were treated with intramedullary pin and cerclage. Moreover, the bandaging duration extended up to day 60 and the dislocation of a pin was observed in only one case. Vijaykumar et al. (19) stated that animals were moderately able to stand on the operated limb within 2 weeks after pinning.

Fracture fragments were easily positioned. The LCP was effectively used in this integration process. However, weak structure of the bone was clearly observed during drilling and screwing. Due to the pressure incurred at the fracture moment, a serious contusion was observed both

in skin and subcutaneous tissues. Moreover, the anatomic region of the occurred fracture was not supported by muscle and was just under the skin layer. These situations did not prevent recovery of subcutaneous tissues and the coverage of skin over the plate. However, the weak and flexible structure of the bone observed in the postpartum period required support with a bandage. Bandages were removed on day 10. There was no adverse condition regarding standing on the treated limb. No mobility limitation on joints because of bandages developed.

Patel et al. (22) and Faleiros Resende et al. (26) reported that swelling was observed on the operation line on the 4th postoperative day, but there was no need for intervention and it disappeared in the following days. They indicated that edema can be a result of surgical trauma, aseptic inflammation, and lymphatic injury. In the present study, all cases showed a similar development. No intervention was made for correction. In the postoperation time, inflammatory swelling regressed; however, another swelling was apparent due to callus caused by osteosynthesis by leaving gaps among fragments in the operation area to eliminate shortening of the bone.

In the postoperative period, at the beginning ecchymotic and then mortified areas developed due to the pressure of the calving chain/rope on and around the operation line in four cases. Treatment of these cases required a long period. We thought that this situation was the result of delay in recovery of contused tissues due to cut venous feeding. At the 6th postoperative week, fracture and open wound infection occurred in one case. No intervention was made and the calf was transferred to a slaughterhouse because of the negligence of the owner.

Patel et al. (22) reported that calli start to establish radiodense bridges among broken fragments at day 30. More compact, dense, and evident callus development starts at day 45 and the cavity along the fracture line finally fills at day 60. Prabhakar et al. (11) applied an external bandage with plaster of Paris in two calves with metacarpal and metatarsal fractures. They stated that callus development was observed at the 9th week. Martens et al. (10) reported that periosteal callus developed at the 8th week in a tibial fracture case; nevertheless, in this period, total immobilization of the fracture fragments was not possible through external cooptation. Faleiros Resende et al. (26) reported that bone consolidation was completed at day 60 of the postoperative period in calves with humerus fractures treated with polypropylene nails.

In our study, development of calli among calves exhibited differences. In all cases, on radiographs in the first 2 weeks, there were no significant findings regarding development of calli. In some cases, there was a fibrocartilage callus at the 3rd week. Thereafter, at the 4th week, a radiodense callus was remarkable. In this period,

standing posture was improved as well clinically. After the 5th week, an evident callus and cooptation were remarkable on X-ray images; at the 9th and 10th weeks, development of the callus was almost completed. Vijaykumar et al. (19) and Patel et al. (22) reported that migration of pins was experienced when they administered the intramedullary nailing method.

In the present study, calves were treated in the first week of the postpartum period. Although the metacarpus has weak bone structure in the postpartum period, we did not encounter screw loosening. Nevertheless, a relaxation was observed in spongiosis screws implanted in condyles because the bone was weaker in comparison with the corpus. Additionally, it can be concluded that bandaging for 10 days is useful to support implants. Due to the weak structure of the metacarpus, drilling and screwing were done as carefully as possible in the present study. We also considered that using spongiosis screws would be more appropriate for the distal fragment. External bandage support was ensured because of the bone fragment for necessary anatomic resistance and it was inadequate at the distal part.

Görgül et al. (4) claimed that amputation is a significant economic indication in open and infected metacarpus fractures. Conventional treatment of these cases would take a long time and can be costly, or might result in death. They stated that wounds recovered perfectly and walking capability returned without any loss in calves, and amputation should be considered as a useful and viable treatment method that minimizes economic concerns.

In the present study, none of the cases turned into open fractures. In four cases, a local separation of sutures and aseptic serous accumulation were observed. We thought that these cases were the result of negligent attitudes of animal owners concerning postoperative maintenance conditions. Calves recovered in a short period of time within the framework of an appropriate treatment protocol. For a calf that experienced late-period trauma and infection and not respond to treatment, amputation was suggested, but the owner refused. The animal was then sent to the slaughterhouse.

Among ruminants, while the proximal growth plate of the metacarpus closes upon birth, the distal growth plate remains open until 2–2.5 years of age (27). A literature review did not present any data regarding either longitudinal or latitudinal growth of bone in the treatment of metacarpus fractures.

Although the fracture line was located outside of the growth plate, that would not prevent elongation of the bone; delay in formation of bridges among broken fragments can be explained by insufficient vascular supply of the soft tissues in the region. In our study, for the metacarpus length of treated calves, although the differences between

the 1st day (163 ± 1.98 mm) and the 120th day (182 ± 1.80 mm) and 365th day (199 ± 1.62 mm) were found to be statistically significant, there was no problem in walking quality and general health clinically. In comparison with the intact limb, the differences between values at days 45, 120, and 365 were found to be significant. Regarding healthy and operated legs, there was a nonsignificant difference among values at days 1, 45, 120, and 365 for metacarpus length and periosteal (cortex) and endosteal (medulla) diameter (Table 1).

Akeson et al. (28) and Uhthoff et al. (25) reported that rigid plate immobilization caused thinning of the bone cortex under the plate at the end of the 9–12 months following plate application on long bones based on biomechanics tests and macroscopic and histological examinations. Janes et al. (29) reported that mineral content of the bone increases not only along the fracture line, but also on all surfaces where the plate is in contact with the compact bone in a rigid way, after plate osteosynthesis of long bones.

Based on the radiographical examination, development of a callus between fragments was observed at the end of the 5th postoperative week. In this period, the radiographical measurements did not indicate longitudinal growth in the metacarpus. Although growth plates were not affected, continuance of repair along the fracture line can be considered as a reason for this delay. Additionally, increases in diameters of the metacarpal cortex and medulla might be related to latitudinal growth.

Principles of fracture treatment for calves are reported as quick return to normal limb function, optimum aesthetic results, prevention of bone complications such as joint diseases or malunion, and simple postoperative care (20,21,30).

All calves were able to stand on their limbs on the next day. At the end of the 1st week, they could bear weight on their feet. We observed that bandages applied for 1 week did not cause any limitations for adjacent joints. Calves presented progressive recovery. Muscle atrophy was initially observed but resolved shortly in affected limbs. Malunion did not take place. However, we noted that is necessary to keep the postoperative maintenance conditions at the optimum level.

In conclusion, because juvenile bones do not provide sufficient physical strength for implants, we decided that LCPs are associated with a good prognosis for surgical repair of distal metacarpal fractures in newborn calves. We concluded that LCPs can be used in treatment of metacarpus fractures in calves, and future studies are required to focus on the retrieval of blood circulation as soon as possible in terms of recovery of soft tissue and ensuring a supply of sufficient nutrition to bone tissue.

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