Management of comminuted fractures of the proximal phalanx in horses: 64 cases (1983–2001)

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Objective—To report the outcome of surgical treatment of comminuted fractures of the proximal phalanx in horses.

Design—Retrospective study.

Animals—64 horses.

Procedure—Medical records and radiographs were reviewed to obtain information regarding signalment, fracture classification, and treatment. Follow-up information was obtained by telephone conversation or evaluation of production records.

Results—Thirty-eight horses had moderately comminuted fractures of the proximal phalanx. Two horses were euthanized immediately. Fractures of the proximal phalanx in 36 horses were repaired with open reduction and internal fixation with a successful outcome in 33 (92%) horses. Reconstruction of the fracture was performed in most horses by use of a long curved incision, transection of the collateral ligament of the metacarpophalangeal or metatarsophalangeal joint, and open exposure of the proximal articular surface of the proximal phalanx. Twenty-six horses had severely comminuted fractures of the proximal phalanx. Six horses were euthanized immediately. One horse was euthanized after 9 days of treatment with a cast alone. Severely comminuted fractures of the proximal phalanx in 13 horses were treated with an external skeletal fixation device, and fractures healed in 8 of those horses. Six horses with severely comminuted fractures of the proximal phalanx were treated with transfixation pins incorporated into a fiberglass cast, and fractures healed in 4 horses.

Conclusions and Clinical Relevance—Moderately comminuted fractures of the proximal phalanx can be successfully repaired; however, fractures that are too severe to permit accurate reconstruction of the fragments remain difficult to treat and horses have only a fair prognosis for survival. (J Am Vet Med Assoc 2004; 224:254–263)

Comminuted fractures of the proximal phalanx are common injuries in horses. Most comminuted fractures of the proximal phalanx occur in racehorses; however, these fractures may also occur as accidents in the pasture or during other athletic activities. Difficulties in the management of horses with fractures of the proximal phalanx and the generally poor prognosis associated with these fractures have been reviewed. Invasive open reduction techniques have resulted in high postoperative infection rates of as much as 55%. Furthermore, stability of the fracture is difficult to achieve in severely comminuted fractures of the proximal phalanx. Instability causes displacement of the fracture fragments and often compromises blood supply, which leads to poor fracture healing. During healing of comminuted fractures of the proximal phalanx, osteoarthritis of the metacarpophalangeal or metatarsophalangeal joint as well as the proximal interphalangeal joint can develop and cause permanent residual lameness. The severity of this lameness can be life-threatening and can cause laminitis in the contralateral limb. Results of treatment of horses with comminuted fractures of the proximal phalanx have been variable. In 1 study, horses were treated with half-limb casts if the fracture did not have longitudinal stability or the proximal articular surface of the proximal phalanx could not be adequately reconstructed. In that study, 3 of 3 horses treated with half-limb casts and 4 of 8 horses treated with lag-screw fixation returned to breeding. In a previous study performed by our hospital, 3 of 6 horses with moderately comminuted and 4 of 13 horses with severely comminuted fractures of the proximal phalanx survived. All 5 horses with severely comminuted open fractures of the proximal phalanx died. The purpose of the study reported here was to report the outcome of surgical treatment of comminuted fractures of the proximal phalanx in horses.

Criteria for Selection of Cases

Medical records and radiographs of 64 horses examined at the George D. Widener Hospital for Large Animals, New Bolton Center, University of Pennsylvania, from January 1983 to July 2001 were reviewed. Fractures of the proximal phalanx were considered comminuted if there were ≥ 3 major fragments. Fractures with small fragments in the diaphysis or articular surfaces of the proximal phalanx that did not directly affect treatment decisions (ie, fractures that could be repaired as if the smaller fragments were not there) were not included in the study. Horses with simultaneous skeletal injuries, such as fractures of the third metacarpal or metatarsal bone or disruption of the suspensory apparatus, were excluded from the study.

Procedures

Horses with fractures were allocated into 2 groups on the basis of radiographic findings. Radiographic views included lateromedial, dorsopalmar or dorsoplantar, dorsomedial-palmarolateral oblique or dorsomedial-plantarolateral oblique, and dorsolateral-palmaromedial oblique or dorsolateral-plantaromedial
Lateral, and dorsopalmar or dorsoplantar views confirm fractures in the frontal and sagittal planes. Additional oblique radiographic views were also obtained if needed to assess fracture configuration.

Moderately comminuted fractures were those fractures with 1 fragment that extended the length of the bone (an intact cortex) and in which the majority of fragments could be reconstructed with internal fixation (Fig 1). Severely comminuted fractures were those fractures in which there was no intact length of cortex and interfragmentary reconstruction was determined not to be feasible (Fig 2). Although horses were not observed at the trot, lameness was determined on a scale of 0 to 5 with 0 being clinically normal and 5 being non-weight-bearing.

**Moderately comminuted fractures of the proximal phalanx**—Potassium penicillin G (20,000 U/kg [9,091 U/lb], IV, q 6 h) and gentamicin (2 or 6.6 mg/kg [0.91 or 3.0 mg/lb], IV, q 8 h or q 24 h, respectively) were administered to all horses before surgery. Antimicrobials were administered perioperatively and continued for 3 to 5 days after surgery. Phenylbutazone (2.2 to 4.4 mg/kg [1.0 to 2.0 mg/lb], IV) was administered to all horses before surgery. Phenylbutazone (2.2 mg/kg) was continued after surgery every 12 or 24 hours depending on the degree of lameness observed as the horse ambulated in the stall. Phenylbutazone was continued until horses were able to ambulate without signs of discomfort, usually 3 to 5 days. Horses were treated preoperatively with IV fluid therapy and electrolytes if they had physical examination

![Figure 1](image1.png)

Figure 1—Lateromedial (A,C,E) and dorsopalmar (B,D,F) radiographic views of moderately comminuted fractures of the proximal phalanx in horses. Notice that there is at least a single strut of intact bone extending the length of the proximal phalanx.

![Figure 2](image2.png)

Figure 2—Lateromedial (A,C) and dorsopalmar (B,D) radiographic views of severely comminuted fractures of the proximal phalanx in horses. Notice that there are no intact struts of bone extending the length of the proximal phalanx.
findings (tacky mucous membranes, increased heart rate, or prolonged skin tent) or CBC or serum biochemical abnormalities (high PCV, high concentrations of total solids in plasma, or azotemia) consistent with dehydration. Horses were treated preoperatively with fluids and administered electrolytes orally if they had decreased fecal output or dry fecal consistency.

Open reduction and internal fixation by use of an open approach with collateral ligament transection was performed in most horses with moderately comminuted fractures of the proximal phalanx. In all horses in which the collateral ligament of the metacarpophalangeal or metatarsophalangeal joint was transected, the lateral collateral sesamoidean ligament was also transected. For brevity, the surgical approach will be referred to as an open approach with collateral ligament transection. Horses were sedated before anesthesia was induced with xylazine (0.27 to 0.33 mg/kg [0.12 to 0.15 mg/lb], IV) or detomidine (0.007 to 0.009 mg/kg [0.003 to 0.004 mg/lb], IV), which was occasionally combined with butorphanol (0.02 mg/kg [0.009 mg/lb], IV). A sling attached to an overhead electric hoist was fitted to the horse while it was sedated. Anesthesia was then induced with 5% guaifenesin administered to effect, followed by ketamine (2.6 mg/kg [1.2 mg/lb], IV). Alternatively, anesthesia was induced with ketamine (2.6 mg/kg, IV) and diazepam (0.1 mg/kg [0.045 mg/lb], IV) occasionally combined with thiopental (0.25 to 0.5 g, IV as needed). Anesthesia was maintained with halothane or isoflurane. Horses were positioned in lateral recumbency with the most fragmented cortex uppermost. The limb was circumferentially prepared for aseptic surgery from the coronary band to the proximal metacarpus or metatarsus. A tourniquet was not used. A dorsomedial or dorsolateral approach was selected on the basis of the configuration of the fracture. An intact strut of bone or 2 well-apposed large fragments that could form such a strut was positioned away from the side of the incision, which placed the more severely comminuted portion of the bone ipsilateral to the incision. A curved skin incision was made. The skin incision was curved from the proximal extent of the proximal phalanx. CDE = Common digital extensor tendon.

The incision extended dorsally through part of the common digital extensor tendon or long digital extensor tendon until it reached the proximal dorsal fracture line and then the incision was extended distally through the same tendon for the length of the sagittal fracture plane. Subperiosteal dissection along the margins of the fracture fragments was performed with a scalpel or sharp periosteal elevator. Luxation of the metacarpophalangeal or metatarsophalangeal joint exposed the articular surface of the proximal phalanx, and the fracture planes were debrided of hematoma, fibrin, and small fragments of bone and cartilage by use of a sharp pick or bone curettes (Fig 3). The proximal articular surface of the proximal phalanx was reconstructed first by use of standard 4.5-mm cortical bone screws in lag-screw technique. Fragments were held in reduction digitally or with bone reduction forceps. The sequence of reconstruction began with attachment of the fragments deepest from the incision and proceeding outward, toward the incision. The bone screws were directed dorsopalmar or dorsoplantar and positioned most proximally so that the lateral-medial screws could be placed distal to the sagittal groove of the proximal phalanx (Fig 4). Smaller fragments were secured...
with 3.5-mm lag screws or small (2.0- or 3.0-mm) pins. Although 4.5-mm screws were used in all of the moderately comminuted fractures repaired with internal fixation, occasionally 1 or two 5.5-mm screws per repair were used when the possibility of interference between screws or small pins was minimal. In 1 horse with a comminuted fracture of the middle portion of the diaphysis of the proximal phalanx that did not permit stable fragment reconstruction by use of lag screw technique alone, a 5-hole, 3.5-mm dynamic compression plateb was used in combination with additional 4.5-mm screws. Lavage of the exposed tissues was performed by use of large amounts of sterile polyionic fluids with broad-spectrum antimicrobials such as polymixin B (500,000 U), bacitracin (50,000 U), or neomycin (1 g). If bacitracin was unavailable, 1 g of erythromycin was substituted.

Although accurate reduction of the proximal articular surface of the proximal phalanx was ensured by direct exposure of the articular surface, the most distal portion of the fracture was usually reconstructed with the aid of radiography or fluoroscopy with image intensification.

Simple 3-piece fractures of the proximal phalanx that were minimally displaced were repaired by use of open reduction without transection of the collateral ligament or through stab incisions with the aid of fluoroscopy with image intensification.

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The joint capsule and ligaments were apposed in a simple interrupted pattern by use of size-1 polyglactin 910.c The remaining tissues were apposed similarly with 2-0 polyglactin 910 sutures. The skin incision was closed with 2-0 nylon,d 2-0 polypropylenee in a simple interrupted or continuous pattern, or stainless steel skin staplesf were used. Drains were not used. A fiberglass cast incorporating the foot in slight extension and extending to the proximal metacarpus or metatarsus was placed. Occasionally, mild heel elevation was used to level the weight-bearing surface of the cast if the limb was determined to be inadequately extended within the cast. Horses with hind limb fractures recovered from anesthesia by use of the pool-raft recovery system. Horses with forelimb fractures recovered from anesthesia on a 185 X 132 X 22-cm foam mattress g in the recovery stall, and standing was assisted by the use of head and tail ropes.

Cast changes were routinely performed after 2 weeks unless there was evidence of complications with the cast such as excessive wear of the cast material, cast sores, or the horse had signs of discomfort. Suture removal was performed during cast changes. Cast changes were sometimes performed during general anesthesia as determined by clinician preference and the disposition of the horse. Final cast removal was always performed with the horse standing but moderately sedated.

Severely comminuted fractures of the proximal phalanx—Potassium penicillin G (20,000 U/kg, IV, q 6 h) and gentamicin (2 or 6.6 mg/kg, IV, q 8 h or q 24 h, respectively) were administered to all horses before surgery. Occasionally, horses with open severely comminuted fractures were treated with amikacin (6 to 20 mg/kg [2.7 to 9.1 mg/lb], IV, q 24 h) rather than gen-
tamicin because amikacin has greater efficacy against gram-negative organisms than gentamicin. Amikacin was also used if the owner did not have financial constraints or it was preferred by the clinician. Antimicrobials were discontinued 2 to 3 days after surgery unless horses had open severely comminuted fractures or severely comminuted fractures with serum oozing through intact skin. Antimicrobials were continued and changed on the basis of results of bacteriologic culture and susceptibility testing of fluid draining from wounds. Phenylbutazone (4.4 mg/kg, IV) was administered to all horses before surgery. Phenylbutazone (2.2 to 4.4 mg/kg, PO or IV) was continued after surgery every 12 or 24 hours depending on the degree of lameness observed as the horse ambulated in the stall. Phenylbutazone was continued until horses were able to ambulate without signs of discomfort. Horses were routinely treated with phenylbutazone for several weeks. Horses were monitored closely for signs of phenylbutazone toxicity including clinical signs such as oral ulcers, bruxism, change in fecal consistency, as well as CBC and serum biochemical abnormalities such as hypoproteinemia and azotemia. Horses were treated preoperatively with IV fluid therapy and electrolytes if they had physical examination findings or CBC or serum biochemical abnormalities similar to horses with moderately comminuted fractures. Horses were treated preoperatively with fluids and electrolytes if they had decreased fecal output or dry fecal consistency.

Sedation of horses for general anesthesia, anesthetic induction, and maintenance of anesthesia was as described for those with moderately comminuted fractures. Skeletal transfixation techniques were used in horses with severely comminuted fractures of the proximal phalanx. Horses were positioned in lateral recumbency with the affected limb uppermost. The limb was clipped to the level of the proximal metacarpus or metatarsus and aseptically prepared. The conventional pins for the external skeletal fixation device were 9.6 mm in diameter in the threaded portion with an 8.6-mm core diameter and self-tapping in design. Pilot holes for 3 transfixation pins were centered in the middle portion of the third metacarpal or metatarsal bone and centered dorsal to palmar or plantar and perpendicular to the long axis of the bone. A 5.5-mm pilot hole centered dorsal to palmar or plantar and perpendicular to the long axis of the third metacarpal or metatarsal bone was made with a 5.5-mm drill bit through the 5.5-mm drill sleeve placed in a specifically designed drill guide. The drill guide positions the holes at a proper distance between each other as well as parallel to each other. A 7.94-mm drill bit was used in conjunction with the 7.94-mm drill sleeve placed in the designed drill guide, and the Jacobs chuck was used to manually enlarge the pilot holes. A second 2-cm skin incision was made laterally, parallel to the long axis of the third metacarpal or metatarsal bone at the junction of the proximal and middle one-third of the bone. A 5.5-mm pilot hole centered dorsal to palmar or plantar and perpendicular to the long axis of the third metacarpal or metatarsal bone was made with a 5.5-mm drill bit through the 5.5-mm drill sleeve placed in a specifically designed drill guide. The drill guide positions the holes at a proper distance between each other as well as parallel to each other. A 7.94-mm drill bit was used in conjunction with the 7.94-mm drill sleeve placed in the designed drill guide, and the Jacobs chuck was used to manually enlarge the pilot holes. A second 2-cm skin incision was made laterally, parallel to the long axis of the third metacarpal or metatarsal bone at the junction of the distal and middle one-third of the bone. A second 5.5-mm pilot hole was made with the 5.5-mm drill sleeve placed in the designed drill guide. This hole was enlarged with the 7.94-mm drill bit through the 7.94-mm drill sleeve within the designed drill guide. Two 2-cm stab incisions were made parallel to the long axis of the third metacarpal or metatarsal bone and over the drill holes on the medial aspect of the leg. The end-threaded 7.94-mm pins were placed into the holes. Once the pins were placed, stainless-steel tapered-sleeves were placed over the threaded portions of the pins and a fastener was placed over the pin and

Figure 5—Photograph (A) and dorsopalmar (B) radiographic view of a horse with a severely comminuted fracture of the proximal phalanx treated with an external skeletal fixation device. Notice the two 794-mm tapered-sleeve trans cortical pins placed in the third metacarpal bone.
tightly. The tapered sleeves were then incorporated into the vertical sidearm frame.

If required, arthodesis was performed by use of autologous cancellous bone grafts and placement of several transarticular 5.5-mm bone screws from the proximal dorsal portion of the proximal phalanx to the distal palmar or plantar portion of the third metacarpal or metatarsal bone through stab incisions guided by fluoroscopy.

All horses with open severely comminuted fractures that were treated were treated with the external skeletal fixator. In closed severely comminuted fractures, certain clinicians preferred to treat horses with pins incorporated into a fiberglass cast. One transfixation pin was placed 1 cm proximal to the phalangeal scar of the distal third metacarpal or metatarsal bone, centered dorsal to palmar or plantar and perpendicular to the long axis of the bone. A second pin was positioned similarly across the middle portion of the diaphysis of the third metacarpal or metatarsal bone. In certain horses, a single 9.6-mm threaded transfixation pin was placed in the distal metaphysis of the third metacarpal or metatarsal bone and two 5.6-mm diameter unthreaded half-pins were placed obliquely in the diaphysis. A loop of 18-gauge stainless-steel wire was placed through the hoof wall to help hold the digit in correct alignment during application of the cast. Six or 7 rolls of 5-inch wide fiberglass casting tape were used. The casting tape was applied circumferentially, and the tape was slit with a scalpel as it passed over the pins. After the first several layers of casting tape were applied, the tape was applied heavily on the distal side of each pin for additional support. Polymethylmethacrylate was placed around the interface of each pin with the cast material for additional strength. After the cast had hardened, the protruding pins were cut with a hacksaw. Horses with transfixation pins or the external skeletal fixation device recovered from general anesthesia by use of a pool-raft recovery system.

Transfixation casts were maintained for 4 to 6 weeks. Following removal of the transfixation pins, the cast was replaced with a half-limb cast without transfixation pins. This cast was maintained until fracture healing was observed on radiographic examination, which included the presence of bridging callus across fracture lines. Casts were changed as needed if complications associated with the cast were observed.

Telephone follow-up or production records were used to assess the outcome of treatment. A successful outcome was given to horses in which the fractures healed and, if intended, were able to be used for breeding. Although lameness evaluation at the trot was not performed, horses that were not intended for breeding (ie, geldings) had no signs of discomfort when released into a pasture.

Statistical analyses—Statistical comparison of breed distribution, compared with the hospital population, was performed by use of a $\chi^2$ test. A value of $P < 0.05$ was considered significant.

Results

There were 28 Thoroughbreds (27 racehorses and 1 show hunter), 28 Standardbred racehorses, 3 Arabian (2 racehorses and 1 showhorse), 3 warmbloods, and 2 polo ponies included in the study. This breed distribution was not significantly different than the hospital caseload of horses with musculoskeletal injuries. There were 41 females, 17 stallions, and 6 geldings. Median age of affected horses was 3 years (range, 2 to 16 years).

The majority (46/64; 72%) of horses sustained comminuted fractures of the proximal phalanx during racing or race training. Eighteen of the 27 (67%) Thoroughbred racehorses fractured the proximal phalanx during training exercise and 5 (19%) horses sustained fractures during a race. One (3.7%) Thoroughbred fractured the proximal phalanx during recovery from anesthesia for repair of an incomplete midasigittal fracture of the proximal phalanx of the same limb, 1 (3.7%) Thoroughbred fractured the proximal phalanx in the stall during confinement for a tendon injury, and 2 (7.4%) Thoroughbreds sustained fractures of the proximal phalanx in the pasture.

Fourteen of 28 (50%) Standardbred racehorses sustained comminuted fractures of the proximal phalanx during racing, 8 (29%) during training, 3 (11%) in pasture accidents, 1 (3.6%) during recovery from general anesthesia, 1 during training after the administration of perineural analgesia, and 1 after being turned out into a pasture with a suspected midasigittal fracture of the proximal phalanx in the same limb.

Activities in the remaining 9 horses that sustained comminuted fractures of the proximal phalanx included polo (n = 2), lunging (1), exercise in a pasture after administration of perineural analgesia (1), begrudging (teasing) accident (1), and slipping on ice (1). One stallion fractured the proximal phalanx during transport with another stallion. The circumstances during which 2 horses sustained comminuted fractures of the proximal phalanx were unavailable.

Thirty-eight forelimbs (18 left and 20 right) and 26 hind limbs (12 left and 14 right) were affected. In Thoroughbreds, comminuted fractures of the proximal phalanx were sustained in the left (n = 6) and right (10) forelimbs and the left (4) and right (7) hind limbs. In Standardbreds, comminuted fractures of the proximal phalanx occurred in the left (n = 9) and right (7) forelimbs and the left (5) and right (7) hind limbs.

All horses were severely (grade 4 or 5) lame. Horses had obvious signs of pain, swelling, and instability of the proximal phalanx. Most horses arrived at the clinic with cotton bandages on the affected limb. A few horses had rigid casts or Kimzey splints placed on the affected limb before they were transported. Eight horses had open severely comminuted fractures of the proximal phalanx. Four horses with severely comminuted fractures had extensive bruising with serous fluid oozing through intact skin surrounding the proximal phalanx of the affected limb.

Moderately comminuted fractures of the proximal phalanx—Thirty-eight horses had moderately comminuted fractures. Two stallions were euthanized immediately for economic reasons. Fractures in the remaining 36 horses were treated with open reduction and internal fixation. Twenty-eight horses were
treated with open reduction and internal fixation with collateral ligament of the metacarpophalangeal or metatarsophalangeal joint transection. Seven horses were treated with open reduction and internal fixation without collateral ligament transaction, and 1 horse was treated with internal fixation through stab incisions guided by fluoroscopy. Mean ± SD surgery time for open reduction, internal fixation, and cast application was 25 ± 11 hours (median, 22 hours; range, 16 to 45.5 hours). The complexity of the repairs varied; mean ± SD number of bone screws used per repair was 6.6 ± 2.3 per proximal phalanx (median, 3; range, 3 to 13 screws).

Mean ± SD time for cast coaptation was 45 ± 7.5 days (median, 42 days; range, 21 to 168 days). The 8 horses without lateral collateral ligament transaction had some of the shortest coaptation periods ranging from 21 to 42 days (mean ± SD, 37 ± 10.5 days; median, 42 days). However, overall the times were similar to other repair methods. Moderately comminuted fractures of the proximal phalanx healed in 33 of 36 (92%) horses that survived and were treated with only internal fixation. Of the 33 horses that survived, 3 horses trained for racing but did not race. Four Standardbreds (4/8) without lateral collateral ligament transaction were able to return to racing. All surviving horses intended for breeding could carry foals to term or perform as breeding stallions without special care. Although lameness evaluation at the trot was not performed, all horses not intended for breeding (ie, geldings) were comfortable at pasture. There were no postoperative infections in the surviving horses.

Three horses with moderately comminuted fractures of the proximal phalanx were euthanatized. In 1 horse, the hoof was found to be ischemic following cast removal 7 days after surgery. The cast was removed to evaluate and treat the limb, the fixation failed and fracture reduction was lost 2 days later, and the horse was euthanatized. Another horse had severe lameness for 4 months after surgery. Radiography did not reveal signs of osteomyelitis, but the progression of fracture healing did not appear satisfactory. For economic reasons, the horse was euthanatized. One horse developed laminitis of the contralateral limb and was euthanatized 7 months after the original injury.

Severely comminuted fractures of the proximal phalanx—Twenty-six horses had severely comminuted fractures of the proximal phalanx. Six horses (3 fillies, 1 gelding, and 2 stallions) were euthanatized immediately for economic reasons. One horse was treated with a cast alone. By day 3, displacement of the fracture fragments was detected on radiographic evaluation, and by day 9, there was serosanguinous fluid draining through the cast. The cast was removed, necrosis of the skin over 1 of the fracture fragments was observed, and the horse was euthanatized.

Skeletal transfixation techniques were used in 19 horses. Thirteen horses were treated with an external skeletal fixation device, including 9 horses that were treated with the external skeletal fixation device that used 7.94-mm tapered sleeve transcortical pins. Six horses were treated with transfixation pins incorporated into a fiberglass cast.

Of the 13 horses treated with an external skeletal fixation device, 8 had open comminuted fractures of the proximal phalanx and another 4 horses had serous fluid oozing through intact skin overlying the proximal phalanx. One of the 13 horses was initially treated with open reduction and internal fixation with collateral ligament transection although there was no intact strut of bone or 2 fragments that could be reconstructed into a strut. The horse continued to be severely lame after surgery. Radiography performed 8 days after surgery revealed collapse of the fracture fragments. An external skeletal fixation device was applied and the fracture healed. The horse has been lightly ridden as a trail horse.

Seven of the 12 remaining horses survived and the fractures healed. Of these seven horses, 5 were treated with the external skeletal fixation device with 7.94-mm tapered sleeve transcortical pins. Six of the 7 horses have been used for breeding. One horse was euthanatized 11 months after the injury because of chronic lameness despite adequate fracture healing.

Five of the 12 horses treated with the external skeletal fixation device fractured the third metacarpal bone and were euthanatized. One of those horses fractured the third metacarpal bone during recovery from anesthesia, and 3 horses fractured the third metacarpal bone during confinement in the stall 9, 13, and 36 days after surgery. Another horse fractured the third metacarpal bone during recovery from anesthesia following removal of the external skeletal fixation device. The fracture was repaired with 2 bone plates and an autologous cancellous bone graft. The proximal phalanx and third metacarpal fractures healed. The horse was scheduled for discharge from the hospital 18 months after the original injury when it sustained a transverse fracture of the healed proximal phalanx in its stall. The horse was euthanatized at the request of the owner.

Of the 7 horses that survived and had severely comminuted fractures of the proximal phalanx that healed, 2 horses had the external skeletal fixation device removed 58 and 20 days after skeletal transfixation and a single transfixation pin was left in place and incorporated within a short leg cast for 1 and 1.25 months, respectively. The surviving 7 horses had chronic lameness. Two horses underwent surgical arthrodesis of the metacarpophalangeal or metatarsophalangeal joint (Fig 6).

Six horses with severely comminuted fractures of the proximal phalanx were treated with transfixation pins that were incorporated into fiberglass casts. Four horses survived and the fractures healed. All horses had residual lameness but have been used for breeding. One horse fractured the third metacarpal bone after removal of the cast and the transfixation pins. The fracture occurred with the horse in a cast that enclosed the hoof and extended to the proximal metacarpus. The fracture of the third metacarpal bone was repaired successfully with 2 bone plates and an autologous cancellous bone graft. Arthrodesis of the metatarsophalangeal joint was performed in 1 horse by use of three 5.5-mm transarticular cortical bone screws placed with lag-screw technique several weeks after the original trans-
In a previous study, we reported poor results with mal phalanx through stab incisions is usually indicated for reconstruction of comminuted fractures of the proximal phalanx. Complications with the surgical approach and techniques of internal fixation used in that study were common. In that study, 7 horses with moderately comminuted fractures of the proximal phalanx were treated and 4 fractures healed. In the study reported here, internal fixation was successful in 33 of 36 (92%) horses with moderately comminuted fractures of the proximal phalanx. The open exposure of the proximal articular surface of the proximal phalanx during surgery is aggressive; however, the slightly curved surgical approach has the advantage of inducing less avascularity at the incision margins than H or Y incisions that have been previously used. In our previous study, 6 of 13 horses treated with internal fixation (including 6 horses with severely comminuted fractures of the proximal phalanx) developed infections at the surgical site. By use of the approach described in the study reported here, no infections were diagnosed after surgery, although osteomyelitis was suspected in 1 horse. Parenteral antimicrobial prophylaxis was not appreciably different between the 2 studies; however, intraoperative antimicrobial lavage was used more extensively in the study reported here.

Exposure of the proximal articular surface of the proximal phalanx by transection of the collateral ligament of the metacarpophalangeal or metatarsophalangeal joint permits accurate reconstruction of complex fractures. This should not only minimize degenerative changes in the joint but also provide greater stability and comfort via accurate cortical realignment. There were no complications recognized as being associated with the collateral ligament transection. Although we do not know the healing pattern of these ligaments in horses, 6 weeks of cast coaptation appears to be adequate for healing when followed by an additional 2 to 3 months of stall confinement. Accurate fragment reconstruction without transection of the collateral ligament may offer a better prognosis for return to athletic function because all of the horses that were able to return to racing were treated with open reduction and internal fixation without transection of the collateral ligament of the metacarpophalangeal or metatarsophalangeal joint; however, only simple 3-piece fractures that were minimally displaced were treated in this way. It is possible that arthroscopic and fluoroscopic reduction techniques permit a less invasive fixation that may improve outcome. Broken drill bits are a common complication in difficult fracture repair in horses. We are not aware of any adverse effects of this complication.

Severely comminuted fractures of the proximal phalanx in which internal fixation is not possible remain to be extremely challenging injuries. Although cast coaptation alone can occasionally be successful, collapse of the fracture fragments within the cast is inevitable with any degree of weight-bearing because there is no longitudinal stability to these fractures and soft tissue injury ensues. Instability of the fracture also causes marked lameness on the limb. Fracture healing may occur despite this; however, laminitis of the contralateral limb and other complications of severe lameness limit the usefulness of cast coaptation alone.

Transfixation techniques appear to be the most practical means of managing horses with severely comminuted fractures of the proximal phalanx. Transfixation techniques substantially reduce displacement of fragments across a fracture site, compared with traditional half-limb casts without transfixation techniques. Many transfixation techniques have been evaluated in the metacarpus of horses to determine the method that provides the greatest axial stability. No important differences in fracture displacement have been found between the use of parallel pins, divergent pins, or parallel pins with the use of a walking bar.

The use of transfixation techniques is complicated by the large forces associated with weight-bearing. To counteract these forces, the strongest implants are used, which often means an increase in pin diameter. In the study reported here, the use of large diameter threaded pins permitted weight-bearing without signs of pain in most horses for 6 to 8 weeks. However, use of large diameter pins can cause large cortical defects and often a decrease in bone strength. Furthermore,
placement of large diameter pins often causes microstructural damage as well as heat production and thermal damage to the bone.\textsuperscript{15-18} Thermal injury at the bone-pin interface can initiate loosening of the pin and cause osteonecrosis and ring sequestra. Although we have observed ring sequestra in horses treated with transfixation, ring sequestra were not clinically evident in the horses in the study reported here. To reduce microstructural damage and minimize thermal necrosis, a pilot hole approximating but not exceeding the inner diameter of the pin is used.\textsuperscript{15} Furthermore, pilot holes should be drilled at low speeds and use enough axial force to advance the drill bit as quickly as possible,\textsuperscript{16} and the use of nonself-drilling and nonself-tapping pins will further decrease the amount of microstructural damage.\textsuperscript{17}

Unlike a cast, an external skeletal fixation device permits regular evaluation and treatment of traumatized tissues. This is advantageous in the management of open fractures. Treatment of horses with closed fractures by transfixation pins incorporated into a fiberglass cast was successful in 4 of 6 horses. In addition in certain horses, it is prudent to leave at least 1 transfixation pin incorporated into a cast after an external skeletal fixation device is removed. The additional support can help prevent collapse of the fracture, many of which are slow to regain mechanical strength.

A complication of any treatment of severely comminuted fractures of the proximal phalanx is severe osteoarthritis of the metacarpophalangeal or metatarsophalangeal joint. Osteoarthrosis of the proximal interphalangeal joint is also a consistent sequela but less of a problem because the joint may spontaneously fuse. Osteoarthrosis of the metacarpophalangeal or metatarsophalangeal joint in horses with healed comminuted fractures of the proximal phalanx may cause spontaneous fusion; however, in certain instances, delayed surgical arthrodesis may be required to reduce signs of lameness more quickly. Delayed arthrodesis and bone grafting after the initial soft tissue trauma may be desirable and may be used to manage horses with severely comminuted fractures of the proximal phalanx that develop signs of pain caused by osteoarthrosis of the metacarpophalangeal or metatarsophalangeal joint. In our study, delayed arthrodesis was used successfully in 3 horses with severely comminuted fractures of the proximal phalanx.

A potential complication that may develop with external skeletal transfixation techniques is fracture of the third metacarpal or metatarsal bone through a transcortical pinhole. In our study, 7 horses treated with external skeletal fixation sustained fractures of the third metacarpal or metatarsal bone through a transcortical pinhole and only 1 of these horses survived.

One horse fractured the third metacarpal bone during recovery from anesthesia. We presently remove transfixation pins with the horse sedated, but in a standing position, to minimize risk of fracture during recovery. Changes in the design of the external fixation device have been made to decrease stress at the bone-pin interface, increase stiffness of the construct, and decrease the number and size of pins.\textsuperscript{6} The bone-pin interface is the site of pin loosening, bone infection, and bone and implant failure. Slow insertion of the self-tapping pins is essential to minimize heat generation and subsequent bone necrosis that may result in loosening of the pin with or without infection. Furthermore, to increase the stiffness of the fixation device and reduce peak concentrated stresses at the bone-pin interface, smaller transcortical pins (7.94 mm) with tapered sleeves were used recently, which permits the bone to carry higher loads before failure.\textsuperscript{9} This model of external skeletal fixation was used in 5 horses in our study, and no fractures of the third metacarpal or metatarsal bone developed with an external skeletal fixation device after these changes were initiated.

In the study reported here, 1 Arabian sustained a fracture of the third metatarsal bone through a pin-hole; the pin (9.6 mm) may have been proportionally too large for the size of the horse. Proportionally larger cortical bone defects caused by transcortical pins decrease bone strength and increase the risk of catastrophic failure.\textsuperscript{12,14} Use of the smaller tapered-sleeve transcortical pins (7.94 mm) in this horse would have reduced the likelihood of decreased bone strength caused by a large diameter hole without decreasing stability at the fracture site or decreasing stiffness of the fixation device.

References


