In vitro comparison of transfixation and standard full-limb casts for prevention of displacement of a mid-diaphyseal third metacarpal osteotomy site in horses

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Objective—To compare transfixation and standard full-limb casts for prevention of in vitro displacement of a mid-diaphyseal third metacarpal osteotomy site in horses.

Sample Population—6 forelimbs from 6 horses euthanized for reasons not related to the musculoskeletal system.

Procedure—A 30° osteotomy was performed in the mid-diaphysis of the third metacarpal bone. Two 4.5-mm cortical bone screws were placed across the osteotomy site to maintain alignment during casting. Two 6.35-mm Steinmann pins were placed from a lateral-to-medial direction in the distal aspect of the radius. A full-limb cast that incorporated the pins was applied. An extensometer was positioned in the osteotomy site through a window placed in the dorsal aspect of the cast, and after removal of the screws, displacement was recorded while the limb was axially loaded to 5,340 N (1,200 lb). Pins were removed, and the standard full-limb cast was tested in a similar fashion.

Results—The transfixation cast significantly reduced displacement across the osteotomy site at 445 N (100 lb), 1,112 N (250 lb), 2,224 N (500 lb), and 4,448 N (1,000 lb), compared with the standard cast.

Conclusion and Clinical Relevance—A full-limb transfixation cast provides significantly greater resistance than a standard full-limb cast against axial collapse of a mid-diaphyseal third metacarpal osteotomy site when the bone is placed under axial compression. Placement of full-limb transfixation casts should be considered for the management of unstable fractures of the third metacarpal bone in horses. (*Am J Vet Res* 2000;61:1633–1635)

Transfixation casting is a form of external skeletal fixation that has been in use since the 1950s.[1,2] Transfixation casts incorporate stainless-steel pins placed through a bone proximal to the fracture site. This allows transfer of the axial weight-bearing forces from the limb through the pins to the cast, which results in a significant decrease in the transfer of weight-bearing forces to the bones distal to the pins.[3] A half-limb transfixation cast resulted in a significant decrease in displacement across an osteotomy site on the proximal phalanx in an in vitro study of the forelimb in horses.[4]

The ability of a full-limb transfixation cast to protect the distal part of the forelimb in horses has been evaluated. Compared with a standard full-limb cast, a walking-bar cast incorporating 2 transfixation pins placed in the distal portion of the radius resulted in a more uniform and centric decrease of compressive forces and eliminated bending and torsional forces measured from the third metacarpal bone.[5] In another study, differences were not detected in bone strain on the distal portion of the radius or the dorsal cortex of the mid-diaphyseal region of the third metacarpal bone when a full-limb cast and transfixation cast were compared.[6] Results of this latter study suggest that a full-limb transfixation cast does not offer advantages over a standard cast when managing metacarpal fractures in horses.

The purpose of the study reported here was to compare the ability of a full-limb transfixation cast with that of a standard full-limb cast for prevention of collapse across an oblique mid-diaphyseal third metacarpal osteotomy site. Our hypothesis was that a transfixation cast would significantly decrease displacement.

Materials and Methods

Specimens—Six forelimbs were collected from adult horses euthanized for reasons not related to the musculoskeletal system. Limbs were disarticulated at the elbow joint, wrapped in towels soaked in saline (0.9% NaCl) solution, sealed in plastic, and stored at –20 C until tested. Limbs were thawed at room temperature (approx 21° C) for 24 hours prior to testing.

Osteotomy—A 10-cm incision was made through the skin to expose the dorsal cortex of the mid-diaphyseal region of the third metacarpal bone. An oscillating bone saw was used to create an osteotomy site that extended palmarodistally from the dorsal cortex at a 30° angle to the longitudinal axis of the bone. A goniometer was used to approximate the 30° angle. The dorsal aspect of the osteotomy site began approximately 2.5 cm proximal to the mid-diaphyseal cortex of the third metacarpal bone. Two 4.5-mm cortical bone screws were placed as lag screws across the osteotomy site to stabilize the third metacarpal bone during placement of the full-limb cast, using techniques described by the Association

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for the Study of Internal Fixation. Holes for the placement of the screws were drilled prior to performing the osteotomy. Screws were placed 1 cm proximal and 1.5 cm distal to the dorsal cortex of the mid-diaphyseal region of the third metacarpus.

Placement of casts—Two 6.35-mm smooth Steinmann pins were placed through two 5.5-mm holes in the distal portion of the radius. The distal pin was located 3 cm proximal to the attachment of the lateral collateral ligament and was inserted in a lateral-to-medial direction, using a power drill. A second pin was placed in identical fashion 4 cm proximal and parallel to the first pin. Pin ends were cut with a bolt cutter 3 cm above the skin surface.

Following pin placement, a full-limb cast was applied distally from the elbow joint. The cast incorporated the foot. The foot was placed in a weight-bearing position parallel to the ground during casting. A double layer of stockinette was applied, followed by 2 rolls of resin-impregnated foam.[a] Next, 4 rolls of 4-inch and 5 rolls of 5-inch fiberglass cast tape[b] were applied. Casting material was incised to allow the cast tape to be wrapped over the transfixation pins, incorporating them into the cast. One roll of 5-inch fiberglass cast tape was used to cover the foot. The cast was allowed to harden for 30 minutes prior to testing. After mechanical testing of the transfixation cast, the transfixation pins were removed, the cast was evaluated for damage, and the standard full-limb cast then was tested.

Mechanical testing—A 3 × 9-cm window was cut in the dorsal aspect of the cast over the third metacarpal bone, and the 2 lag screws were removed. An extensometer[c] then was positioned in the third metacarpal bone. Shallow 2-to 3-mm grooves were created, using an oscillating bone saw. Grooves were placed proximal and distal to the osteotomy site so each knife edge of the extensometer could be anchored in the dorsal cortex of the third metacarpal bone to prevent slipping during testing. Rubber bands were placed around the cast and each arm of the extensometer to maintain position.

Limbs were placed in a mechanical testing machine[d] with the proximal aspect of the radius attached to a load cell that was attached to a screw-driven hydraulic loading ram. The proximal aspect of the radius was held in position by bolts placed around its circumference. The foot was constrained by a foot plate with a toe stop. All limbs were loaded in axial compression to a maximum load of 5,338 N (1,200 lbs). Data was recorded at 0.2-second intervals, using a software package[e] designed for the testing machine. The full-limb transfixation cast was tested first, then the pins were removed, and the standard full-limb cast was tested.

Statistical analysis—Results obtained at 445 N (100 lb), 1,112 N (250 lb), 2,224 N (500 lb), and 4,448 N (1,000 lb) of axial compression were compared between groups (casts) by use of paired Student *t*-tests. Differences were considered significant at $P \leq 0.05$.

Results

The full-limb transfixation cast significantly reduced displacement of the ostotomy site at 445 N ($P = 0.027$), 1,112 N ($P = 0.011$), 2,224 N ($P = 0.001$), and 4,448 N ($P = 0.0001$), compared with the standard full-limb cast. Mean displacement across the osteotomy site at 445 N was 0.13 mm (range, 0.03 to 0.23 mm) for the transfixation cast and 1.89 mm (range, 0.33 to 4.37 mm) for the standard cast. Mean displacement at 1,112 N was 0.34 mm (range, 0.07 to 0.75 mm) for the transfixation cast and 3.61 mm (range, 0.66 to 6.75 mm) for the standard cast. Mean displacement at 2,224 N was 0.48 mm (range, 0.19 to 1.01 mm) for the transfixation cast and 4.93 mm (range, 3.15 to 8mm) for the standard cast. Mean displacement at 4,448 N was 1.51 mm (range, 0.32 to 3.04 mm) and 8.63 mm (range, 7.00 to 12.75 mm) for the transfixation and standard casts, respectively. In the transfixation cast, 3 limbs were recorded in tension and 3 in compression, whereas all limbs in the standard cast were recorded in compression.

Discussion

Analysis of results of the study reported here indicated that at 445, 1,112, 2,224, and 4,448 N of axial compression, there was significantly less displacement across an osteotomy site in the third metacarpal bone of horses when the limb was supported in a transfixation cast than when supported in a standard full-limb cast. The transfixation cast was effective at transferring axial loads from the bony column to the cast, thereby protecting the distal region of the limb. Moreover, our results suggest that, when a forelimb is loaded in axial compression, a full-limb transfixation cast will provide greater axial stability across a fracture of the third metacarpal bone in horses than will a standard cast.

Paired limbs were not used in this study, unlike in a previous study that evaluated displacement across an osteotomy site.[4] In the study reported here, we used the same limb to compare the effect of the 2 casts. The transfixation cast was tested first. Minimal displacement developed with this cast and, as a result, the same limb could be used to test the standard cast. This study design eliminated variables that would have existed had we used paired limbs. For example, cast application, window size in the cast, extensometer placement, osteotomy site location, or angle did not vary. Casts were examined between tests for buckling or delamination; structural changes were not detected.

Cortical defects > 10% of the bone diameter act as stress concentrators and cortical defects > 20% of the bone diameter linearly decrease torsional bone strength.[7] Three 6.35-mm holes placed in the distal portion of the radius of horses do not significantly decrease the torsional breaking strength of the bone.[8] Therefore, we concluded that removal of the transfixation pins prior to testing the standard full-limb cast would not affect results.

The metacarpal osteotomy that we performed simulates a fracture configuration in which the proximal fragment is able to displace distally into the soft tissues, primarily the suspensory ligament. This design may allow extrapolation of results to an unstable fracture of the diaphysis of the third metacarpal bone.

The tensile surface of the third metacarpal bone is reported to be the dorsomedial,[5,9] dorsal,[10] and dorsolateral[11] aspect of the bone. In the study reported here, the extensometer measured distraction (tensile strain) across the osteotomy site in 3 of the 6 limbs evaluated in transfixation casts. This could be a result of eccentric loading of the limb, which created a bending force on the bone within the transfixation cast. It also may have been attributable to the protection that the transfixation cast provided. In the transfixation casts, displacement of the proximal segment along the osteotomy site was not detected, and, as a result, the proximal fragment engaged the distal fragment along the palmar cortex. This created a small bending force that was measured as distraction on the dorsal cortex of the bone. Compression was recorded from the extensometer in all limbs supported in a full-limb cast because of the amount of displacement, even at low loads.

In previous studies that evalauted full-limb transfixation casts[6] and walking casts,[12] unidirectional strain gauges were used to measure surface strain on the cortices of the third metacarpal bone while the limb was loaded in axial compression. Unidirectional strain gauges have limitations, because they measure surface strain at 1 site on the bone. This does not reflect what is happening to the entire bone during weight bearing. Results of our previous study[6] did not reveal a difference in bone strain recorded from the dorsal cortex of the third metacarpal bone between the 2 types of full-limb casts. Results of the study by Brommer et al[12] also did not reveal a difference in bone strain at this location; however, results of that study did reveal significant decreases in bone strains recorded from the other 3 sides of the bone when the limb was loaded in a full-limb walking cast (equivalent to a full-limb transfixation cast). Results of the study reported here indicate that a full-limb transfixation cast significantly decreased the in vitro transfer of weight-bearing loads to the third metacarpal bone, minimizing displacement at the osteotomy site. Even at loads of 4,448 N, mean displacement at the osteotomy site was only 1.28 mm. Limbs of healthy, walking horses are loaded with approximately 2,224 N (500 lb) of force.[13] In our study, mean displacement for the 6 limbs in transfixation casts at these loads was only 0.34 mm. This small amount of motion should provide more than adequate stability for fracture healing.

The effect of the size and number of pin holes on the torsional breaking strength of the radius has been evaluated in horses.[8] A significant decrease in breaking strength was not detected when 6.35-mm holes or pins were placed in a lateral-to-medial direction through the distal region of the radius. Results of the study reported here, which used osteotomy as a model for fracture, support the use of full-limb transfixation casts for management of unstable fractures of the third metacarpal bone in horses. However, in our study, limbs were loaded in vitro in axial compression. Results may differ in vivo because of torsional and bending forces placed on a weight-bearing limb.

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[a]3M Custom Support Foam, 3M Animal Care Products, St Paul, Minn.

[b]Vetcast Plus, 3M Animal Care Products, St Paul, Minn.

[c]Extensometer, WSU model 200, Washington State University, Pullman, Wash.

[d]Baldwin Testing Machine, Baldwin Locomotive Works, Philadelphia, Pa.

[e]Baldwin Test Control Program, Mechanical Engineering, Pullman, Wash.

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