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EVALUATION OF THE SURGICAL REPAIR OF
EQUINE ACCESSORY CARPAL (PISIFORM) BONE FRACTURES

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MASTER OF SCIENCE

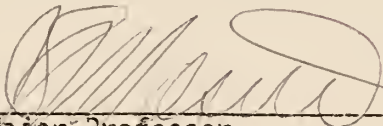
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INTRODUCTION

Fracture of the accessory carpal bone in the horse has been an enigma for veterinary surgeons. There have been few changes in the treatment of this type of fracture since the turn of the century.

Veterinary surgery, especially in the area of orthopedics, has made great advances in the past quarter century. With the development of aseptic surgery, gas anesthesia and high quality metals, the surgeon is leaping hurdles that were thought impossible several years ago.

Accessory carpal (pisiform) bone fractures are a devastating injury to the equine athlete. When this injury is encountered, it has been dealt with conservatively with a guarded prognosis for the animal returning to its former level of competition. There is no reference in the veterinary literature that deals with this subject thoroughly. There are no articles describing the surgical repair of this fracture by internal fixation using the lag screw principle.

The purpose of this project was two fold: First, to perfect and evaluate a surgical technique for the repair of vertical fractures of the equine accessory carpal bone and secondly, to critically evaluate the degree of mechanical lameness and bone healing associated with accessory carpal bone fractures treated by one of three methods. The horses in Group I were treated conservatively with rest for six months. Group II horses were treated with surgical repair fourteen to twenty-one days post fracture and rest for

six months. Group III horses were treated with surgical repair immediately following fracture and rest for six months.

The horses were studied at thirty day intervals for lameness and radiographical signs of healing. Each accessory carpal bone was examined grossly and histologically at the end of the experiment to evaluate the type of healing and mechanical factors that contributed to the horse's lameness.

LITERATURE REVIEW

Introduction

In the past several decades many advances have been made in orthopedic surgery. The greatest progress has been made in the areas of early post fracture ambulation and in the full return of function of the affected part.³⁰ Fractures of the equine accessory carpal bone have not enjoyed the benefits of this progress. There have been few changes in the accepted treatment or prognosis for this type of fracture since its description by Share-Jones in 1907.³⁸ This type of fracture has been of such low incidence that few veterinary surgeons have seen sufficient cases on which to make meaningful conclusions as to the best method of treatment. The feelings of many veterinary surgeons were reinforced by the late Dr. Jenny. When asked how he handled this type of fracture he would respond, "I try very hard to avoid having anything to do with them!"²⁴

The following review is an attempt to summarize and update the published and unpublished information on accessory carpal bone fractures. Included in this review are responses obtained, from over twenty equine practitioners and academic clinicians, to a survey on accessory carpal bone fractures.

Anatomy

The accessory carpal bone is situated prominently on the carpus, palmar to the lateral aspect of the trochlea of the radius and the ulnar carpal bone. The accessory carpal bone, unlike other carpal bones, does not directly bear weight. It may be regarded as a sesamoid

bone interposed in the course of the tendons of the flexor carpi ulnaris and ulnaris lateralis. Its position enables the two muscles to act at a mechanical advantage in flexing the carpus.

Embryologically, the accessory carpal bone appears at 250-290 days of gestation from one ossification center.¹⁴ The two muscles attaching to this bone develop morphologically from two separate areas. The flexor carpi ulnaris develops along with the flexor group and is supplied by the ulnar nerve, while the ulnaris lateralis develops with the extensor group and is supplied by the radial nerve. The flexor carpi ulnaris inserts on the proximal aspect of the accessory carpal bone by a short, strong tendon and blends with the flexor retinaculum. The ulnaris lateralis inserts on the lateral and proximal palmar border of the bone. Both muscles function to flex the carpus and extend the elbow. The discoid shape of the accessory carpal bone aids in its function to support the lateral and palmar aspect of the carpal canal. The bone is the lateral point of attachment of the carpal fascia that completes the flexor retinaculum and carpal canal in which lies the digital flexor tendons, carpal synovial sheath, medial palmar or second common palmar digital artery and nerve.¹² (Fig. 1)

The lateral aspect of the accessory carpal bone is convex and rough. A smooth groove crosses its proximal part obliquely distal and slightly dorsal. The groove contains the long tendon of the ulnaris lateralis that is given off the parent structure just proximal to the carpus. This small rounded tendon, enveloped in a synovial sheath, passes distal and slightly dorsal to insert on the

fourth metacarpal bone. The dorsal border of the accessory carpal bone has two articular facets. The proximal concave facet articulates with the caudal aspect of the lateral facet on the trochlea of the radius (styloid process or ulnar remanent). The distal facet is convex and articulates with the ulnar carpal bone. The dorsal articulations are continuous with the radiocarpal joint.

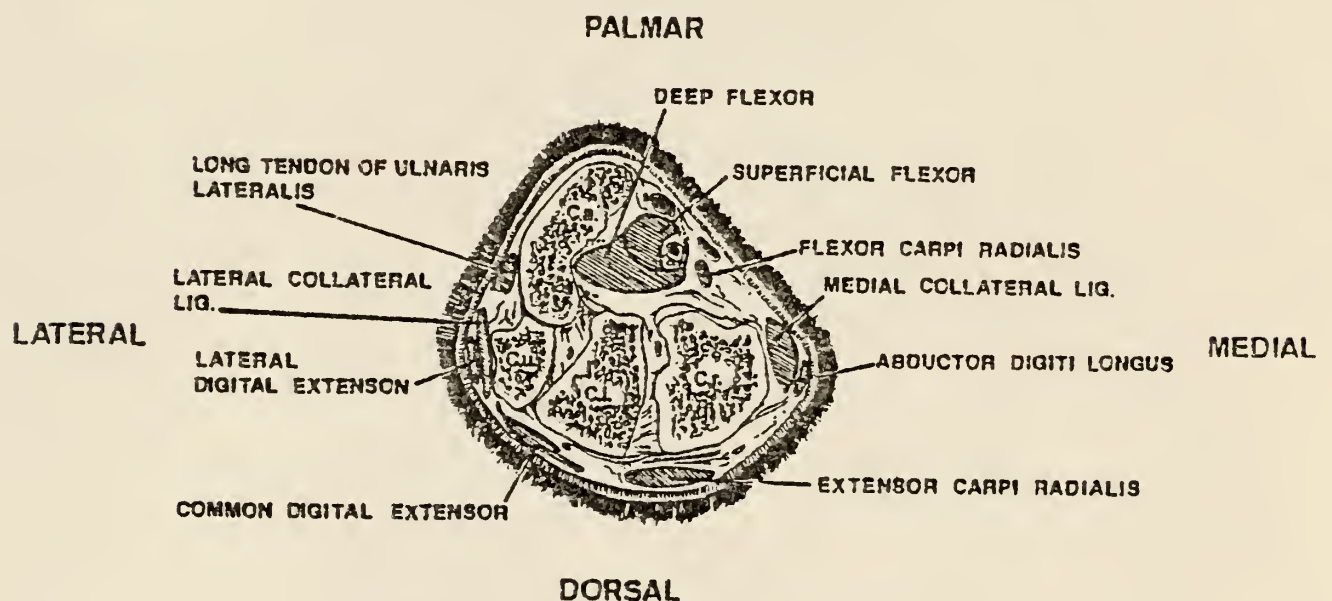


Fig. 1 Anatomy of the Equine Carpus

The accessory carpal bone is firmly attached to the adjacent bones by four ligaments (accessorioulnar, accessoricarpoulnar, assessorioquartal and the accessorimetacarpal). These ligaments firmly anchor the dorsal aspect of the bone to the carpus but not the area palmar to the lateral groove. The accessory carpal bone is richly supplied with blood through its tendonous and ligamentous attachments which completely surround the body of the bone. Most

of these structures are supplied by the caudal interosseous, collateral ulnar and median arteries as well as branches of the brachial artery. (Fig. 2) The nerve supply to the accessory carpal bone and communicating structures is derived from the ulnar nerve. This nerve divides into two terminal branches just proximal to the carpus. Of the two branches, the dorsal branch emerges between the tendons of insertion of the flexor carpi ulnaris and ulnaris lateralis and ramifies on the fascia and skin of the dorso-lateral aspect of the carpus. The palmar branch unites with the median nerve to course distally.

1. Attachment of the main tendon of the ulnaris lateralis
2. Attachment of the flexor carpi ulnaris tendon
- A. Accessorioulnar liagment
- B. Accessoriocarpoulnar liagment
- C. Accessorioquartal liagment
- D. Accessoriometacarpal liagment

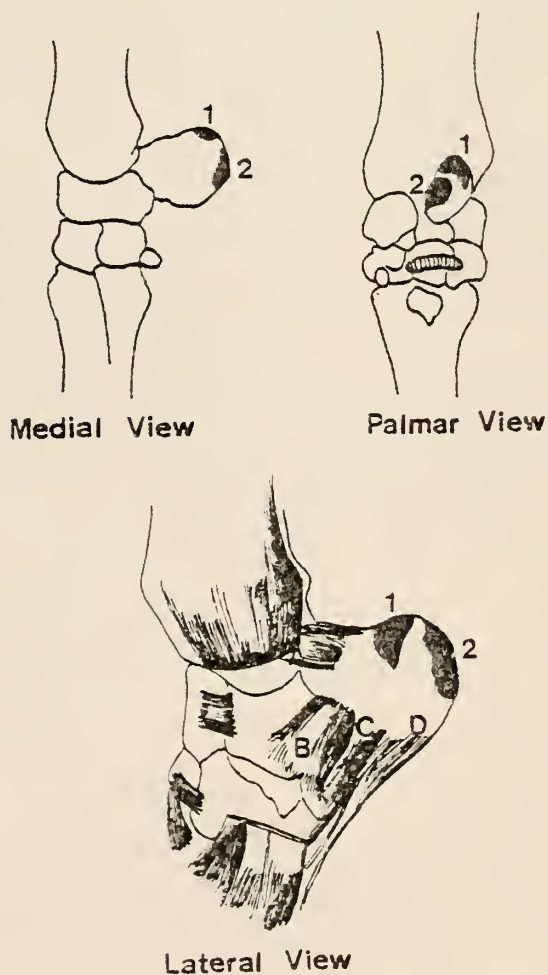


Fig. 2 Ligamentous and Tendonous Attachments to the Accessory Carpal Bone

Incidence and Type of Fracture

Traumatic fracture of the bones of the carpus are common equine injuries. The incidence of carpal fractures as an economic loss has not been reported in the literature except to state that it is high.

Accessory carpal bone fractures are relatively uncommon, occurring in 1% to 10% of all carpal fractures reported.^{21,31,43,52} The characteristic fracture of the accessory carpal bone is in the vertical plane.^{2,15,17} Usually, the fracture is more or less through the center of the bone so that a considerable portion remains attached to the articular segment. Occasionally, the line of fracture is such that two-thirds of the accessory carpal bone has become separated at the anterior margin of the lateral groove.³⁹ This fracture is quite often associated with some degree of comminution.¹⁵ Bone fragments are found at either the proximal or distal border adjacent to the fracture line or may be present on both sides of the fracture.³² The other plane of fracture occurs transversely.⁶ This horizontal fracture is very rare and the prognosis is grave if the proximal portion is displaced by the tension of the free muscles attached to its proximal border.³²

Etiology

Its prominent position, renders the accessory carpal bone most liable to fracture from external trauma of all the carpal bones.^{10,20,38} Cases of external trauma have been reported due to kicks from other horses, loose stirrups³⁷ and polo mallets,⁶ or

getting the leg caught over a fence.²² The incidence of accessory carpal bone fractures tends to be higher in race horses and steeplechasers.^{23,25,51} Several theories have been advanced as to the etiology of this type of fracture. MacKay-Smith, et.al. in 1972 proposed the "bow-string" theory to analyze this type of fracture.²³ Because the fracture is usually of the distraction type with thickened, damaged tendons in the carpal canal and fibrosis of the carpal annular ligament at the level of fracture, these authors contended that the fracture occurs as a result of overloading the limb with the carpus slightly flexed. The "bow-string" resistance of the flexor tendons to further carpal flexion, distracts the palmar portion of the carpal canal in a palmar direction, fracturing the accessory carpal bone, thus tearing the posterior carpal annular ligament or bruising the flexor tendons. A British researcher-surgeon proposed the "nutcracker" theory,³³

- He suggests that there has been repeated trauma to the bone and that ultimately the accessory carpal bone has been fractured because of the crushing "nutcracker" action between the radius and the third metacarpal bone during full flexion. Another author expressed the opinion that asynchronous contraction of the two muscles inserting on the accessory carpal bone causes its fracture. "If the flexor carpi ulnaris contracted while the ulnaris lateralis did not (radial nerve damage?), tensile failure could well occur."³⁵ This type of fracture has been thought to occur as the result of sudden and extreme contraction of the flexor muscles.^{15,38,50}

A case, reported in a draft horse during work, was thought to

result from excess muscle contracture.²⁸

Clinical Signs and Diagnosis

The variation of clinical signs is a striking feature described in the literature. The early literature describes a nonweight bearing lameness that very much resembles a radial nerve paralysis.²⁸ Some horses are only slightly sore and continue to perform.³⁹ The position of the accessory carpal bone favors the formation of a positive diagnosis by palpation, but crepitation on movement may or may not be present.^{1,37,12,15} If the animal is examined immediately after the accident, there is a greater chance to manipulate the bone but this soon becomes impossible due to extensive swelling.¹⁷ The carpal sheath may be distended and bulging between the digital extensors and the ulnaris lateralis.² There is usually sensitivity to sharp flexion or extension of the limb which is disproportionate to or exclusive of a supporting leg lameness.²³

It is not uncommon for accessory carpal bone fractures to accompany other injuries. It has been stated that quite often one of the ligaments of the accessory carpal bone is also ruptured.⁸ One author stated that the intercarpal ligament (accessorioquortal) is usually ruptured in jumpers.⁵¹ In fracture of the accessory carpal bone, thickening of the tendons in the canal and fibrosis of the posterior carpal annular ligament at the level of the fracture are common early adjuncts to the fractures.²³ Villous synovitis with adhesions between the lateral digital extensor tendon and its sheath has been reported in one case.²⁶ Diagnosis is usually confirmed by radiography.¹¹ The radiograph is not a

valuable tool in identifying the age of the fracture. If the fracture has healed with a fibrous union, the fracture line is still easily discernable.^{3,16,49} It was reported that one horse had responded to treatment with an ulnar neurectomy. A nerve block of the ulnar nerve may aid in the diagnosis of this fracture.⁴⁹

Treatment

The treatment of accessory carpal bone fractures has progressed from humane destruction¹⁹ to surgical repair by removal of the posterior fragments or internal fixation.⁴⁸ Most veterinary surgeons agree that conservative treatment is the preferred way to approach this fracture.^{2,5,7,11,16,17,47} There is a wide variation in the prognosis given this fracture by conservative treatment. Some surgeons state that the fracture heals by a painless fibrous union and that following six to twelve months of rest, the animal is sound.^{7,8,41,45} Others state that while the bone heals by a fibrous union following rest, a bony callus never forms and the animal is likely to reinjure the bone with exercise.^{15,38,51} Other surgeons contend that the prognosis is poor with little chance of complete recovery.^{20,42}

There is controversy as to the best method of conservative treatment. Some surgeons recommend external splintage, bandages or plaster casts.^{4,15,29} One equine surgeon feels that bandages and splints increase the tension on the muscles attaching to the bone and add to the distraction of the fragments. Therefore, he advocates the abandonment of use of such fixation devices.³ Complete rest is required and one source recommends that the horse be slung.¹⁵

Surgery of accessory carpal bone fractures has been discussed by Roberts who considered that the most effective treatment of the typical vertical, centrally placed fracture, was removal of the separate palmar portion of the bone.^{33,34} This technique was performed on one horse with the horse later becoming pasture sound.¹³ It has been shown that interruption of the insertion of the flexor carpi ulnaris or removal of the palmar one-fourth of the accessory carpal bone, produced signs of carpal hyperextension and arthrosis.²⁵ It was the opinion of several authors that satisfactory transfixation of such a fracture was impossible.^{17,33,34} One orthopedic surgeon stated, "I have a very hard time seeing how one or two screws placed at right angles to the pull of the flexor carpi ulnaris and ulnaris lateralis can actually hold the bone in rigid immobilization. My feeling is that they would have healed without the screws. So, why risk infection by performing surgery, no matter how low your infection rate is."⁴⁴ Three veterinary surgeons have each repaired three fractures with transfixation screws and have had favorable outcomes.^{36,46,48} Other surgeons have been unsuccessful in their attempts at such repairs.^{3,13,29}

The human literature deals with the placement of a screw in a similarly-shaped carpal bone (carpal navicular or scaphoid bone) in the wrist. The technique of lag screw fixation has been used to stabilize painful nonunion of this bone with good results.²⁷ It has been suggested to treat nonunions of the accessory carpal bone by the technique described for chronic nonunions of the carpal navicular bone in man. This has been accomplished by packing the

fracture line with autologous cancellous bone.³⁶

It is considered by several authors that lameness associated with accessory carpal bone fractures, is due to excessive pressure on the contents of the carpal canal (carpal canal syndrome).²³ To relieve this pressure, surgeons have removed a longitudinal strip of the volar carpal annular ligament. Another interesting comment relative to the pull of the flexor tendons displacing the fragments was made by an equine clinician. He suggested a meshing of the flexor carpi ulnaris tendon--a procedure to correct "over-at-the-knee conformation".⁵⁰ None of the above methods of treatment have been performed on a sufficient number of cases to enable any reasonable conclusions to be drawn on its efficacy.

RESEARCH DESIGN, MATERIALS AND METHODOLOGY

Experimental Design

Nine clinically normal, adult horses, were numbered consecutively and randomly divided into three groups (I, II and III). All horses had their left accessory carpal bone surgically fractured. The three horses in Group I were treated conservatively with stall rest. The accessory carpal bone fractures were surgically repaired in Group II, fourteen to twenty-one days post fracture. The accessory carpal bone fractures were surgically repaired immediately following fracture in Group III horses. The horses in all three groups were handled in the same manner postoperatively.

Selection and Isolation

The horses were between the ages of four and six years, of both sexes and ranged in height from 133 centimeters to 161 centimeters. Weight ranged from 386 kilograms to 522 kilograms (Table I).

The horses were examined to rule out lameness. Five standard radiographic views were taken of the left carpus to assure freedom from gross bone abnormalities of the joint. The horses were tattooed; sprayed with insecticide¹ for external parasites; dewormed with thiabendazole² and trichlorfon³; vaccinated for Eastern and Western equine encephalomyelitis and tetanus⁴; and their feet were trimmed. The horses were placed in isolation for a minimum of fourteen days.

1 Parabomb-M-I, Haver-Lockhart, Bayvet Division of Cutter Labs.,
Inc., Shawnee, Kansas
2 Omnicazole-Six, Merck and Co., Inc., Rahway, New Jersey
3 Combot, Haver-Lockhart, Shawnee, Kansas
4 Equiloid, Fort Dodge Lab, Inc., Fort Dodge, Iowa

Lameness Examination

Several days prior to surgery, each horse was brought to the veterinary clinic and a lameness evaluation was performed by each of three equine clinicians.¹ Each horse was observed at a walk and a trot in a straight line. Each horse was then observed at a trot in a tight circle to the left. The left carpus was fully flexed for two minutes and the horse trotted off in a straight line.

Based on the results of the lameness examination, each horse was given a score of 0 to 6 using the following criteria:

- 0 No lameness observed.
- 1 Slight lameness observed only at a trot after the carpus was flexed.
- 2 Slight lameness observed at a trot in a straight line and moderate lameness observed at a trot after the carpus was flexed.
- 3 Slight lameness observed at a trot in a straight line and severe lameness observed at a trot after the carpus was flexed.
- 4 Moderate lameness at a trot in a straight line.
- 5 Slight to moderate lameness observed at a walk.
- 6 Severe lameness observed at a walk or the animal nonweight bearing on the limb.

The same lameness evaluation procedure was used to evaluate the horses at 60, 90, 120, 150 and 180 days post osteotomy. The animals were also filmed using a super 8 movie camera^{2,3} on each evaluation date.

¹ Bell and Howell 673/XL Focusmatic 8 mm movie camera
² Kodak Ektachrome 160, Type A film
³ Doctors K. J. Easley, J. E. Schneider, R. M. Genetzky

Radiographical Evaluation

Prior to the start of the project, each horse was radiographed using the five standard equine carpal views (dorsal to palmar; lateral to medial; dorsal, palmar, lateral to medial oblique; dorsal, palmar, medial to lateral oblique; and flexed lateral to medial) to rule out gross osseous changes. (Fig. 3)

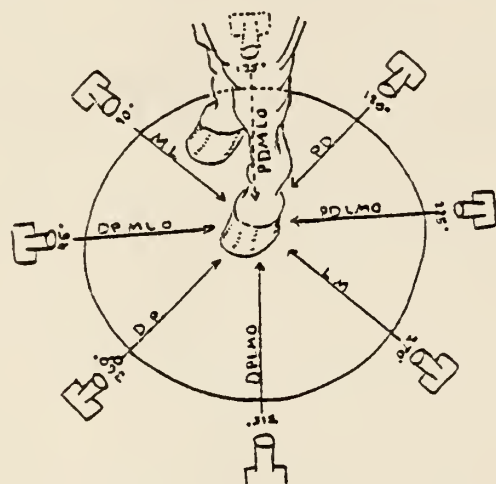


Fig. 3 Four Standard Standing Equine Carpal Radiographic Views: DP, LM, DPLMO, DPMLMO (Not shown is the flexed lateral to medial.)

All horses were radiographed with a Hitachi Condensor Discharge Mobile Unit with a maximum of 125 KVP and 50 MAS¹, Dupont Chronex 4 film² and high plus screens. The films were developed in a Kodak M6-A automatic processor³. The same technique was used on all horizontal exposures (83KVP at .8 MAS with an average target film distance of 90-100 centimeters).

¹ Hitachi, Ltd., Tokyo, Japan
² Dupont Photo Products, Wilmington, Delaware
³ Eastman Kodak Co., Rochester, New York

A radiographic evaluation was done on each horse immediately postoperatively plus re-evaluations at 30, 60, 90, 120, 150 and 180 days later. The evaluations were based on the two views found to best demonstrate the fracture line and screw placement. These two views were horizontally centered over the carpus at 250° - 260° and at 340° - 350° . (Fig. 4) Each of the seven radiographic examinations were evaluated by three clinicians¹, using the following criteria:

- A. Screw Placement and Reduction of the Fracture
 - 1. Good
 - 2. Adequate
 - 3. Not adequate
 - 4. Not repaired
- B. Radiographic Evidence of Movement of the Fracture Fragments or Implants
 - 1. No movement
 - 2. Slight movement
 - 3. Severe movement
- C. Degree of Bone Healing
 - 1. Radiographically healed fracture
 - 2. Radiographically healing fracture
 - 3. Nonhealing fracture
- D. Amount of External Callus Formation
 - 1. No external callus

¹ Doctors K. J. Easley, J. E. Schneider, R. M. Genetzky

2. Slight external callus
3. Moderate external callus
4. Severe external callus

The carpus was removed from the cadaver specimens at the termination of the experiment. A proximal to distal radiograph was taken with an exposure of 300 MC, 75 KVP at .000 5 seconds with a target film distance of 100 centimeters.

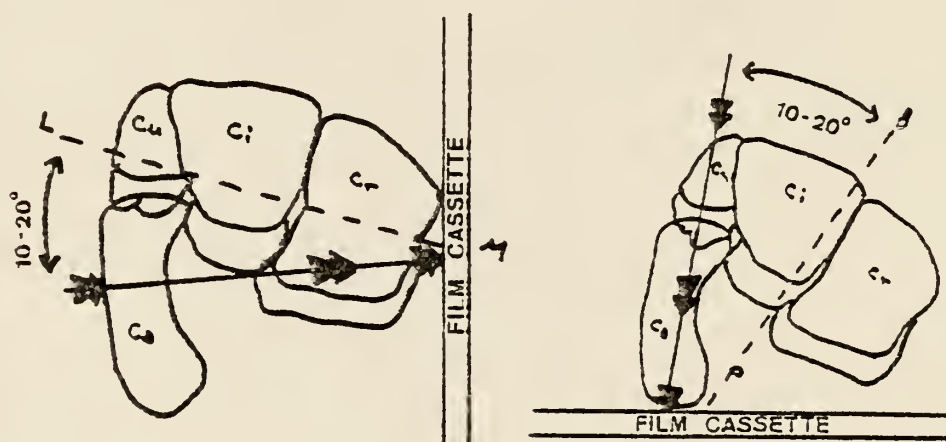


Fig. 4 Two Views Found to Best Demonstrate Fracture Line and Screw Placement

Surgical Preparation and Induction

The day prior to surgery, the leg was clipped with a #40 blade from the pastern proximally to the middle level of the radius. An area 20 centimeters long and three-fourths of the way around the lateral aspect of the carpus, was shaved. The entire clipped area was scrubbed and rinsed three times with tamed iodine.¹ Povidone-iodine² was sprayed over the cleansed area and a sterile elastic gauze³ was applied to the clipped portion of the leg. A Povidone-

¹ Prepodyne Scrub, West Chemical Products, Inc., New York, New York
² Betadine Solution, The Purdue Frederick Co., Norwalk Conn.
³ Sta-Tite, Cheesebrough-Pond's Inc., Greenwich, Conn.

iodine spray was used to moisten the elastic gauze and elastic tape¹ was applied to the limb.

All feed was withheld for twelve hours prior to surgery. Water was withheld on the morning of surgery.

Thirty minutes prior to induction of anesthesia, the horses were premedicated with acepromazine maleate² (.66 mg/Kg, IV). The animals were groomed, their feet cleaned and their legs wrapped from the coronet to the carpus or tarsus. Just prior to induction, the mouth was rinsed with water to prevent entrapped feed from being carried into the trachea with the endotracheal tube.

Anesthesia was induced with a solution containing 500 ml of 5% guifinacin in 5% dextrose³ and 3 grams of thiamylal sodium⁴. This solution was given to effect via a rapid intravenous drip through a 14 gauge 4 inch needle. The animal was placed on the surgery table in right lateral recumbency. The surgery table was padded with a fluid support water mattress⁵. An endotracheal tube⁶ was placed through a mouth speculum into the trachea and attached to a semi-closed circle anesthesia machine⁷. The horse was maintained under light surgical anesthesia with a mixture of Halothane⁸ and O₂. The feet were covered with rubber gloves and the

-
- 1 Elastikon, Johnson and Johnson, New Brunswick, New Jersey
 - 2 Acepromazine Injectable, Ayerst Labs Inc., New York, New York
 - 3 Glycodex Injection, Burns-Biotec Labs, Omaha, Nebraska
 - 4 Surital, Park-Davis and Co., Detroit, Michigan
 - 5 Land and Sky, Lincoln, Nebraska
 - 6 Cole equine endotracheal tube (30 ml.), Intermountain Veterinary Supply Inc., Denver, Colorado
 - 7 Large animal machine with Fluotec 3, Frazer Sweetman Inc., Lancaster, New York
 - 8 Halothane U.S.P., Halocarbon Labs Inc., Hackensack, New Jersey

body draped with a sterile cloth measuring 222 centimeters by 240 centimeters.

The presurgical wrap was removed from the left foreleg and the leg was placed on a sterile rubber drape. The left carpus was aseptically scrubbed once with tamed iodine and a final spray of Povidone-iodine was applied to the limb. The damp, sterile rubber drape was replaced with a dry one and the limb was dried with a sterile towel. A 35 centimeter by 60 centimeter incise-drape¹ was applied to the carpus. The entire animal and table were draped, leaving only a 20 centimeter in length area centered over the lateral aspect of the carpus exposed.

Surgical Procedure #1 - Surgical Osteotomy of the Equine Accessory Carpal Bone

A 15 centimeter elongated C-shaped skin incision was made from just proximal and dorsal to the emergence of the dorsal branch of the ulnar nerve between the tendons of insertion of the flexor carpi ulnaris and the ulnaris lateralis. This incision gently curved dorsal and distal to the lateral digital extensor sheath at the proximal row of carpal bones. The incision then coursed palmar and distal to end just below the carpus over the second metacarpal bone. (Fig.5) The skin, subcutaneous fascia and dorsal branch of the ulnar nerve were reflected in the palmar direction to expose the lateral aspect of the accessory carpal bone. All skin and subcutaneous vessels clamped and if needed, ligated with #000 chromic gut². The sheath

¹ Steri-Drape, 3M Company, 3m Center, St, Paul, Minneapolis
² Ethicon S-112 H. Thicon Inc., Somerville, New Jersey

of the long head of the ulnaris lateralis tendon on the accessory carpal bone, was identified. A three centimeter incision was made vertically over the posterior ridge through the fascia and periosteum. A 20 mm oscillating air saw¹ was used to cut through the lateral cortex of the accessory carpal bone. A 20 mm wide sharp osteotome was inserted, with slight dorsal angulation, into the groove formed by the saw. The osteotome was hit with a mallet to break the medial cortex into the carpal canal. The incised fascia and periosteum were brought into apposition with a simple continuous pattern of #00 polyglycolic acid suture². The horses in Groups I and II had the subcutaneous fascia closed in a simple continuous pattern, using #00 polyglycolic acid suture. The skin was closed with an interrupted horizontal mattress pattern of #00 monofilament nylon³. The drapes were removed and a sterile dressing⁴, elastic gauze and elastic tape were placed over the carpus. The limb was then placed in two stacked 45 X 55 centimeter field compress bandages⁵ from the coronet to the upper mid radius. Anesthesia was discontinued and the horse was placed in a padded stall to recover. The carpus was radiographed with the animal on the surgery table. The horses in Group III had their osteotomies repaired immediately post fracture, as described under Surgery #2.

-
- ¹ Standard bone saw, Stryker Corp., Kalamazoo, Michigan
² Dexon General Closure 7744-51, Davis and Geck, American Cyanamid Company, Pearl River, New York
³ Ethilon 7664, Pitman-Moore, Washington Crossing, New Jersey
⁴ Micropad, 3M Company, 3M Center, St. Paul, Minneapolis
⁵ Johnson and Johnson, Dallas, Texas

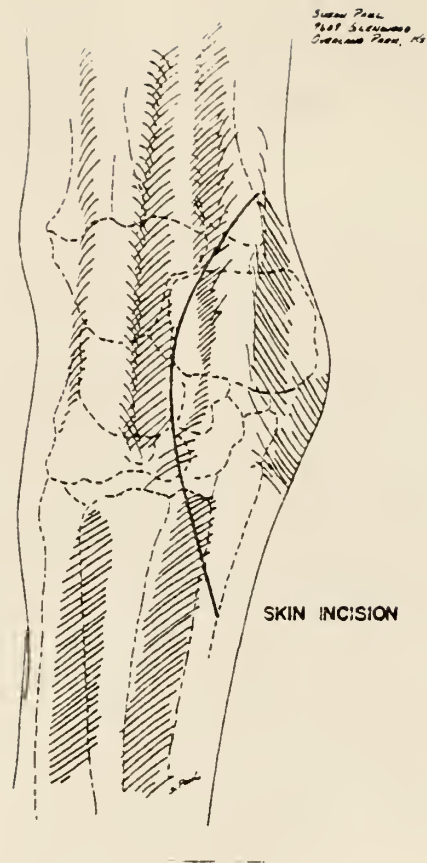


Fig. 5 Skin Incision

Surgical Procedure #2 - Surgical Repair of Vertical Fractures of the Equine Accessory Carpal Bone

The horses in Group II were prepared, anesthetized and draped as described previously.

A skin incision was made parallel to, and two centimeters posterior to the previous incision. Horses from both Groups II and III had the skin and fascial flap reflected over the palmar aspect of the accessory carpal bone.

A two centimeter long skin incision was made on the dorsal aspect of the radiocarpal joint just lateral to the sheath of the

extensor digitorum communis. The limb was supported in full extension by an assistant. The limb was hyperextended to align and compress the fragments. The assistant maintained the limb in the hyperextended position by placing the draped foot against his chest and leaning into the limb. This position allowed his hands to be free. A Carnine-Schneider Equine C-clamp¹ was applied across the accessory carpal bone and the radiocarpal joint. The anterior point of the clamp was inserted into the skin incision and held by the assistant just lateral to the sheath of the extensor digitorum communis at the level of the radiocarpal joint. This position was checked periodically by the surgeon, verifying that the point was in line with the prominent groove for the tendon on the distal aspect of the radius. The posterior set on the C-clamp was placed 5 mm distal to the most proximal aspect of the accessory carpal bone on its posterior lateral border. The posterior set of the C-clamp rested on the lateral aspect of the fascial covering of the bone, 5-10 mm lateral and dorsal to its most palmar aspect. The C-clamp was adjusted to fit snugly into position. The assistant positioned his index finger on the posterior medial aspect of the bone and his thumb on the posterior set of the clamp. In this manner, firm lateral traction was put on the posterior fragment and the C-clamp was secured to the lateral side of the bone, (Fig. 6) A #10 blade² was used to incise the fascia down to the bone under the posterior set of the C-clamp. A 4.5 mm drill with

¹ Bryce L. Carnine: Surgical Arthrodesis of the Distal Interphalangeal Joint in a Horse, Thesis, KSU, 1977

² Bard-Parker Division of Becton, Dickinson and Co., Rutherford, NJ

5 mm calibrations on the shaft, was inserted through the barrel of the C-clamp and a hole approximately 10 mm deep was drilled into the palmar fracture fragment. This hole was drilled to the approximate predetermined depth of the fracture line. A 3.2 calibrated drill was used to form a hole to the approximate depth of the dorsal cortex of the accessory carpal bone usually about 45 to 50 mm. The screw hole was tapped with an elongated 4.5 mm bone tap. The drillings were flushed from the area with sterile saline solution. A 4.5 mm ASIF cortical bone screw¹ of the approximate length to reach the far cortex of the bone but not to penetrate it when tightened (36-46 mm), was placed in the hole and tightened firmly. (Fig. 7)

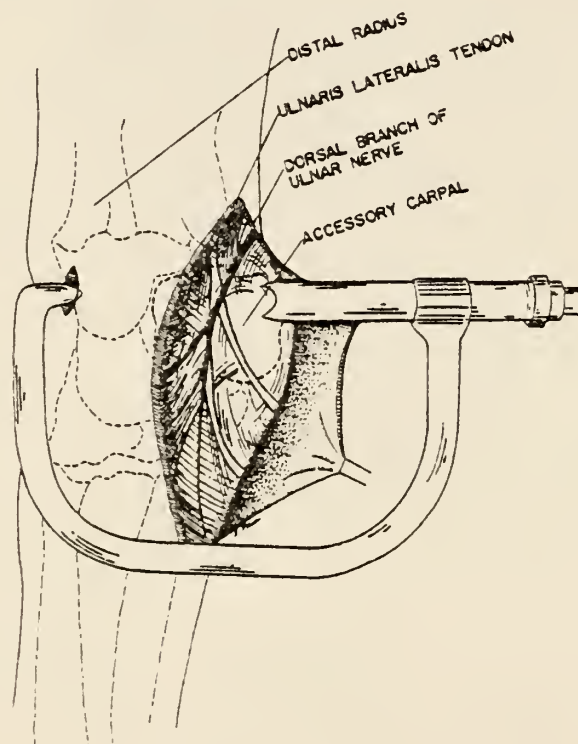


Fig. 6 The C-Clamp in Place for Drilling of the Proximal Screw Hole

¹ Synthes, Ltd., Wayne, Pennsylvania

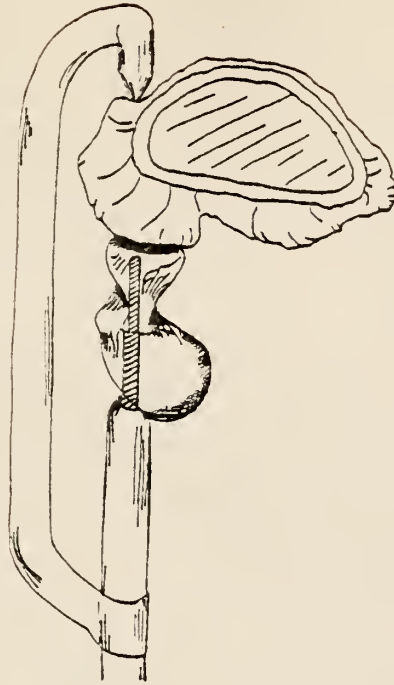


Fig. 7 Proper Placement of the C-clamp in the Median Plane
A 4.5 mm diameter gliding hole is drilled to the fracture line. A 3.2 mm hole is then drilled to the dorsal cortex of the bone.

The C-clamp was loosened and the posterior set swung distally. The assistant, while keeping the leg in full extension, steadied the C-clamp. The clamp was placed with the posterior set 5-10 mm proximal to the most distal aspect of the accessory carpal bone, (Because the bone is slightly thicker distally, the screw may be placed slightly more medial on the bone.) (Fig, 8) The holes were drilled, tapped and the screws placed as described for the proximal fixation. When the screws were tightened, the heads disappeared beneath the fascial covering of the bone. The procedure for screw placement was performed under radiographic control. The area was flushed with sterile saline solution to remove all bone debris. The subcutaneous fascia and skin were closed as described

for Surgery #1. (Fig. 9) The drapes were removed and the leg was bandaged and cared for as described in Surgery #1.

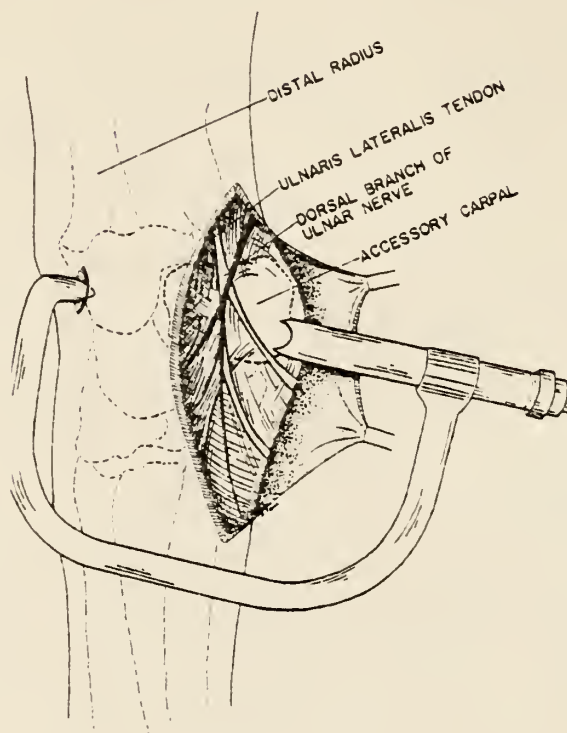


Fig. 8 The C-clamp in Place for Drilling of the Distal Screw Hole

Aftercare

All of the horses were kept in a full leg field compress bandage for fourteen days post surgery. At that time the leg wrap and skin sutures were removed. The horses were treated with penicillin and dihydrostreptomycin¹, 20 ml, bid and phenylbutazone², 2 gms. bid, for five days postoperatively. Each horse was also given oxytetracycline³, 20 mg/Kg, IV, sid from the tenth to the fourteenth postoperative day to label the bone. The horses were confined to a twelve by twelve foot box stall for an additional fourteen day period. At thirty days post surgery, the animals were

¹ Combiotic, Pfizer Inc., New York, New York

² Phenylbutazone Tablets, Med. Tech., Inc., Elwood, Kansas

³ Liguamycin injectable, Pfizer, Inc., New York, New York

placed in small outdoor paddocks fifty by one hundred feet with run-in sheds for a five month period of rest.

Pathology

The nine horses were euthanatized at least six months post surgery. Succinylcholine hydrochloride¹, 200 mgs followed by a solution containing 3 gms of thiamylal sodium and 500 ml of a saturated solution of Mg SO₄, IV, via a fourteen gauge, four inch needle, was used.

A routine necropsy was performed on each horse. The left fore-limb was severed from the trunk at the lower one-third of the radius. The distal part of the limb was removed at the carpometacarpal joint and the carpus radiographed. The skin was then removed and the superficial and the deep flexor tendons removed from the carpal canal. The carpus was examined and the carpal canal photographed. The carpus was then sectioned horizontally with a bone saw, making three to four .5 to 2 centimeter cuts through the accessory carpal bone. The cut sections were examined and photographed.

Bone sections were examined for tetracycline fluorescence under ultraviolet light using two 15 watt black ray woods lamps at approximately 25 centimeters at 60° angles to the specimens. The sections were then photographed using 200 ASA Daylight film². A yellow filter³ was placed over the lens. Exposures were taken at F 5,6, at one, two, four, and eight seconds.

¹ Oraganon Inc., West Orange, New Jersey
² Eastman Kodak Co., Rochester, New York
³ Soligar K-1 or Coastar Y-2, Japan

Following examination, the slabs were fixed in 10% neutral buffered formalin for at least 48 hours. The accessory carpal slabs were then decalcified with Rapid Bone Decalcifier¹ for four to twelve hours. The tissue was readied for embedding with the aid of an autotechnicon². The tissue was embedded in paraffin and sections were cut with a rotary microtome and mounted on slides. The regressive method³ of hematoxylin-eosin stain was performed on all sections.

The histopathological slides were read and selected areas photographed to record the findings.

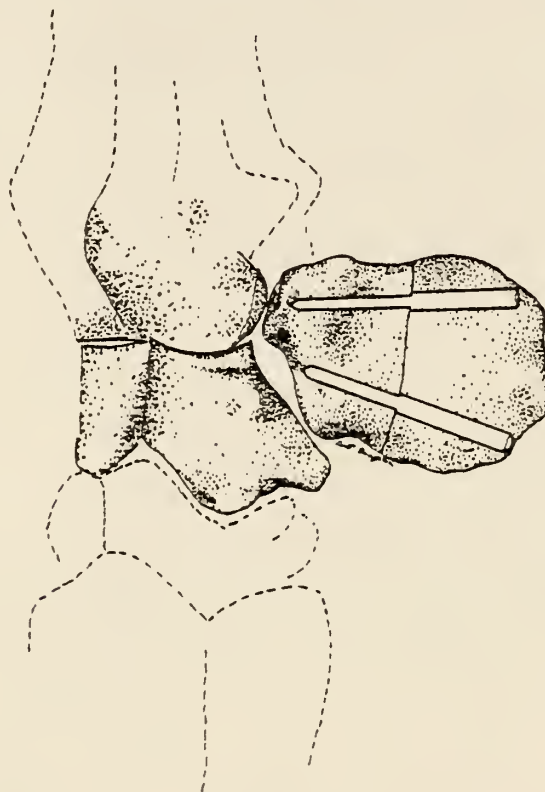


Fig. 9 The Proper Angle and Depth of the Screw Holes in the Accessory Carpal bone

¹ RDO, DuPage Kinetic Labs, Inc., Naperville, Illinois
² The Technicon Co., Chauncey, New York
³ Histo-Tek Stain Pack, Ames Co., Elkhart, Indiana

RESULTS AND DISCUSSION

Accessory carpal bone fractures have been shown to occur most commonly in the vertical plane. I feel that this is the result of a combination of factors. The four ligaments give firm support and stabilization to the segment of bone dorsal to the groove of the long tendon of the ulnaris lateralis muscle. The bone is narrowest and therefore weakest in the area of the lateral groove. The pull of the ulnaris lateralis and flexor carpi ulnaris muscles and the push of the flexor tendons in the carpal canal are concentrated in the area palmar to this lateral groove. When the leg is fully loaded in the partially flexed position, the concentrated forces distract the dorsal segment with forces beyond its tensile strength, thus causing the bone to fracture.

Surgical repair of vertical fractures of the equine accessory carpal bone has been a difficult procedure. The basic principles of internal fixation rely on specific landmarks and precise placement of the implants. This is especially important in the area such as the carpus where damage to tendons medial or lateral to the fixation could lead to permanent disability of the limb. The surgical procedure described with the use of the Carnine-Schneider C-clamp allows for precise screw placement. It is essential that the fracture fragments be aligned with the limb in a hyperextended position and maintained there by an assistant. A tourniquet should not be used above the carpus since it will create tension in the flexor muscles which would then tend to displace the posterior

fracture fragment proximally. The lateral aspect of the groove of the common digital extensor tendon at the distal radius, lies in the same median plane as the dorsal articulations of the accessory carpal bone. The lateral aspect of this groove is the landmark for placement for the dorsal point of the C-clamp. This landmark allows for placement to always correspond to the articular area on the dorsal surface of the bone, thus preventing misplacement of the screws. The posterior fragment should be retracted as far laterally as possible while placing the screws. This will provide maximum room in the carpal canal when the fracture is stabilized. There is little chance of excessive retraction due to the strong attachment of the flexor retinaculum to the accessory carpal bone. Retraction may be aided by the placement of a temporary K-wire in the posterior fragment to facilitate manipulation of this segment of the bone. The dorsal point of the C-clamp is left in the same position at the most distal aspect of the radius for placement of both screws. This allows the screws to be placed at an angle not parallel, thus creating better mechanical stability of the fragments.

There has been some question concerning treatment of nonunions of the accessory carpal bone by cancellous bone grafts packed into the fracture line. This seems to be a poor alternative to screw fixation when one considers the deformity in the curved angle of the accessory carpal bone and the narrowing of the carpal canal (carpal canal syndrome), that could result.

Comminution on the proximal and distal margins of the fracture line is common. This was the case in the osteotomy performed on horse #4. The comminution did not complicate the surgical repair or healing in this case. The fragments may need to be removed if they are displaced.

The radiographic results and lameness evaluations during the course of the project correlated well. All of the horses that had repaired fractures were useably sound by the 150 postoperative day. The fractures on all of these horses had healed radiographically by this time. The results of the 60 and 180 day examinations for the three treatment groups were compared using the Kraskal-Wallis Test and found to be statistically significant at the 10% level. The 180 day lameness examinations for Groups I and II were compared using the Wilcoxin Te t and found to be statistically significant at the 5% level. From these results one can state with confidence that it is superior to treat vertical accessory carpal bone fracture by internal fixation rather than by a long period of stall confinement.

It appeared as though there was a relationship between the amount of movement at the fracture site, external callus and the degree of lameness. The infection in horse #4 stimulated a severe bony callus reaction but the stabilized fracture healed. When the contaminated implant was removed, the horse became usefully sound. This re-emphasized the importance of strict obedience to the rules of aseptic surgery. A mistake in surgical judgement was made in

this case. When I realized that the pre-surgical preparation had not been done properly, surgery should have been postponed. The small size of the accessory carpal bone of horse #3 precluded the use of two screws. The one screw did not completely immobilize the fracture. Motion of the fracture line lead to delayed union and a large amount of callus formation. Adequate stability was maintained in all fractures where two screws were used.

Good compression of the fracture site was achieved in all horses in Group II and all but horse #6 in Group III. It appears from this observation that a delay in fixation of up to three weeks duration does not affect the screw placement or fracture reduction. In a severely traumatized case, it may be to the surgeon's advantage to allow a short period of time for the soft tissues to heal before surgical intervention is contemplated. The lateral callus that was noticed radiographically on all of the horses except horse #6 was due in fact to the damage done to the fascial attachments to the bone at the osteotomy site. The horses were kept on anti-inflammatory therapy several days postoperatively to help minimize this reaction initially. The callus became excessive only on the unstable or infected fractures. The lateral and proximal callus became extensive enough after five months in horse #5 to bridge the fracture gap. This bridging allowed sufficient stability for the fracture to have been radiographically healed by 180 days.

Gross pathological examination revealed that all of the screws had been properly placed in the bone. All of the fractures that

had been reduced and stabilized had healed. The screw in horse #1 had protruded through the distal articulation and into the articular cartilage of the ulnar carpal bone. This did not seem to affect healing or the degree of lameness. Three horses (#1, #8, #9) in which the screws purchased in the dorsal cortex of the bone, were not lame at any of the evaluations. These three horses healed the fastest. Horses #1 and #8 were healed radiographically at sixty days and #9 was healed at 120 days.

The structures within the carpal canal appeared normal on all specimens. The synovial lining of the lateral aspect of the canal beneath the osteotomy site was scarred in horses #1, #2, #6, #7 and #9. The scar at the area where the osteotome had penetrated the carpal canal did not seem to contribute to lameness or delay healing of the fracture.

Gross and histopathological examination of the bones demonstrated healed fractures in all the bones that had been stabilized with lag screws (#1, #3, #4, #6, #8, #9). Unrepaired fractures in horses #2 and #7 developed a fibrocartilagenous nonunion. The unrepaired fracture in horse #5 had a fibrous delayed union. The bone was healing and osteoid had crossed the fracture gap in some areas.

All of the bones fluoresced under U-V light. It would appear that tetracycline dosage of 20 mg/Kg, sid for three days, is an adequate dose for horses. Two of the nine horses developed transient depression and inappetence that disappeared when the tetracycline was stopped.

The results of this experiment demonstrated the feasibility of surgically repairing vertical fractures of the accessory carpal bone. Vertical fractures of the accessory carpal bone that are repaired using the principles of internal fixation, can be expected to heal with a pain free bony union. The affected horses should be able to return to training with an excellent prognosis after less than five months convalescence.

SUMMARY

A technique for the surgical repair of vertical fractures of the equine accessory carpal bone is described. This technique utilized a Carnine-Schneider C-clamp for consistent and precise placement of two lag screws to compress and stabilize the fracture. Radiographic, clinical, gross and histopathological results, from nine horses are discussed.

The results show that vertical accessory carpal bone fractures repaired by lag screw fixation heal rapidly. Horses can return to service with a good prognosis, six months or less, after sustaining a vertical fracture of the accessory carpal bone.

TABLE 1

<u>Horse#</u>	<u>Lip Tatoo#</u>	<u>Age</u>	<u>Sex</u>	<u>Breed</u>	<u>Height</u>	<u>Weight</u>	<u>Group</u>
1	E01-1	4½ yr	G	Quarter	151 cm	522 kg	II
2	E01-2	5 yr	G	Quarter	143 cm	450 kg	I
3	E01-3	5 yr	G	Welch/Quarter	133 cm	386 kg	II
4	E01-4	5 yr	G	Quarter	150 cm	432 kg	II
5	E01-5	4½ yr	G	Quarter	151 cm	420 kg	I
6	E01-7	4½ yr	G	Quarter	151 cm	432 kg	III
7	E01-9	4 yr	Fe	Quarter	150 cm	410 kg	I
8	E02-0	6 yr	Fe	Saddlebred	161 cm	500 kg	III
9	012087	4½ yr	Fe	Thoroughbred	152 cm	522 kg	III

TABLE 2

CLINICAL AND RADIOLOGIC FINDINGS		Post-surgical Evaluation Days						
Lameness Evaluation Scores		0	30	60	90	120	150	180
0	N/A	N/A	N/A	1,8,9	1,8,9	1,4,8,9	1,3,4,6,8,9	1,6,8,9*
1				6	6	3,6		3,4
2					4,3		5	5
3							2	2
4				3,4,7	5	2,5	7	
5					2,7	7		7
6				2,5				
Radiologic Evaluation								
screw placement and reduction		1,4,8						
adequate		6,9						
not adequate		3						
no screws		2,5,7						
movement of the fragment or implant								
no movement		1,3,4,6,8,9	1,4,6,8,9	1,4,6,8,9	1,4,6,8,9	1,3,4,6,8,9	1,3,4,6,8,9	1,3,4,5,6,8,9
slight movement			3	3	3	5	5	
severe movement		2,5,7	2,5,7	2,5,7	2,5,7	2,7	2,7	2,7
degree of bone healing								
healed fracture				1,8	1,8	1,8,9	1,3,4,6,8,9	1,3,4,5,6,8,9
healing fracture			1,3,6,8,9	3,4,6,9	3,4,6,9	3,4,5,6	5	
nonhealing fracture		N/A	2,4,5,7	2,5,7	2,5,7	2,7	2,7	2,7
external callus formation								
no callus		N/A	6	6	6	6	6	6
slight callus			1,8,9	1,8,9	1,8,9	1,8,9	1,8,9	1,8,9
moderate callus			2,3,5,7	3,5,7	3	3	3	3
severe callus			4**	2,4	2,4,5,7	2,4,5,7	2,4,5,7	2,4,5,7

* horse number

** horse #4 had a postsurgical wound infection

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P I C T U R E S

Picture 1 Lateral view of an accessory carpal bone following two years of conservative treatment. The fracture was in the vertical plane through the groove for the long tendon of the ulnaris lateralis muscle.

Picture 2 Medial view of the bone described above.

Picture 3 A view of the bone described above showing the smooth edges of the fracture line.

After two years of conservative treatment, the animal was not working sound. The fracture line was easily discernible radiographically at the time of the horse's death.

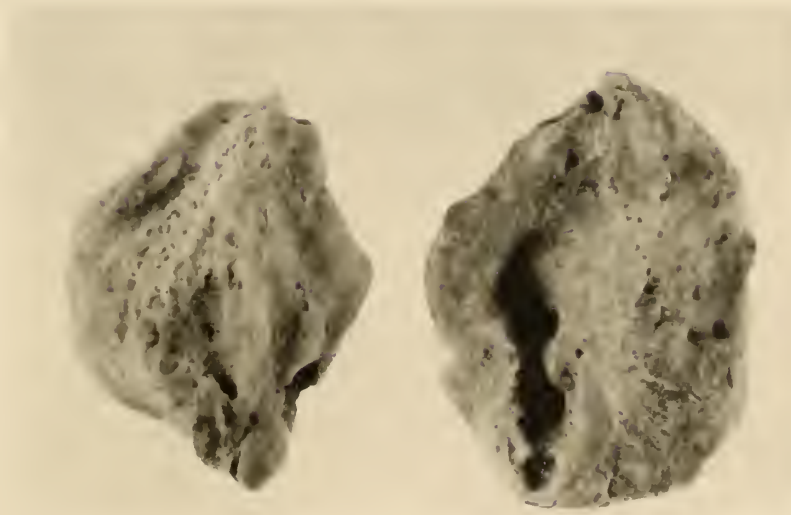
Picture 1



Picture 2



Picture 3



Picture 4

The Carnine-Schneider C-clamp, drill guide and elongated instruments

- A. Elongated 3.2 mm drill with 5 mm calibrations on the shaft
- B. Elongated 4.5 mm drill with 5 mm calibrations on the shaft
- C. Elongated hexagonal screw driver
- D. Elongated 4.5 mm cortical bone tap with 5 mm calibrations on the shaft
- E. Carnine-Schneider C-clamp drill guide
- F. 4.5 mm drill guide sleeve
- G. 3.2 mm drill guide sleeve
- H. ASIF screw hole measuring device

Picture 5

A C-shaped skin incision made on the lateral aspect of the carpus. The skin, subcutaneous fascia and the dorsal branch of the ulnar nerve have been reflected over the palmar aspect of the accessory carpal bone.

Picture 6

The 3 cm long skin incision over the lateral aspect of the common digital extensor tendon at the distal aspect of the radius

Picture 4



Picture 5



Picture 6



Picture 7 Proper placement of the C-clamp drill
guide for drilling the proximal screw
hole

Picture 8 The assistant surgeon steadies the
C-clamp while supporting the limb in
the hyperextended position. Lateral
traction should be placed on the palmar
aspect of the accessory carpal bone.

Picture 9 The proper placement of the C-clamp
on a cadaver specimen

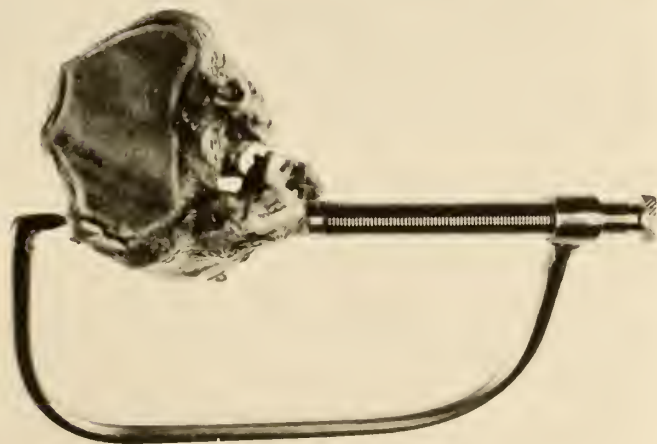
Picture
7



Picture
8



Picture
9



Picture 10

Drilling the 4.5 mm gliding hole in the palmar fracture fragment

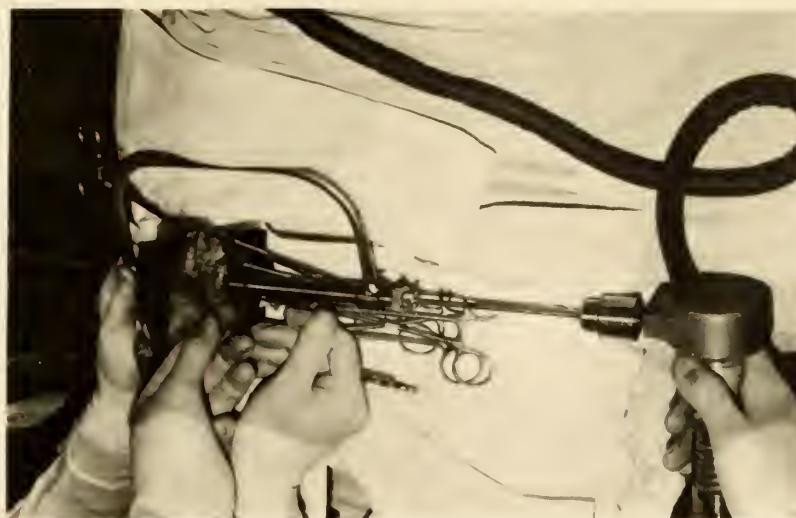
Picture 11

A proximal to distal radiograph of the proper placement of the C-clamp. The 4.5 mm gliding hole has been drilled in a cadaver specimen.

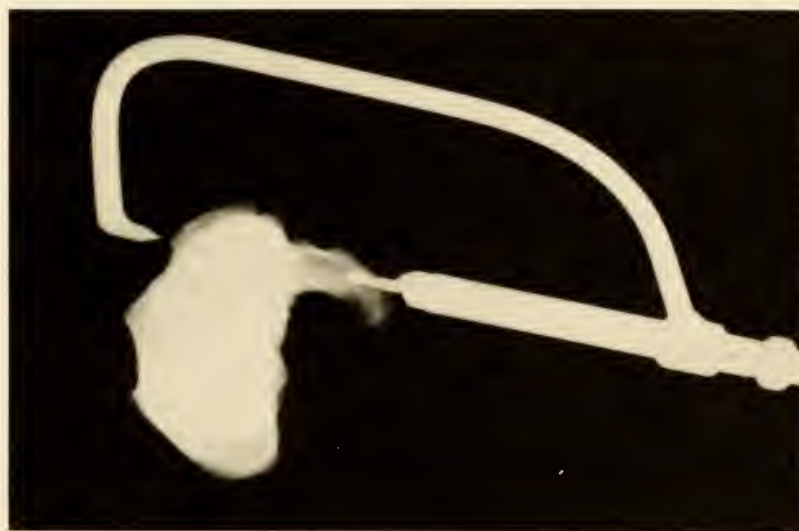
Picture 12

Drilling the 3.2 mm hole in the dorsal aspect of the accessory carpal bone. It is important to determine the depth of the drill holes from the preoperative radiographs.

Picture 10



Picture 11



Picture 12



Picture 13 Tapping the proximal screw hole

Picture 14 Final tightening of the proximal screw to compress the fracture fragments before the distal screw hole is drilled

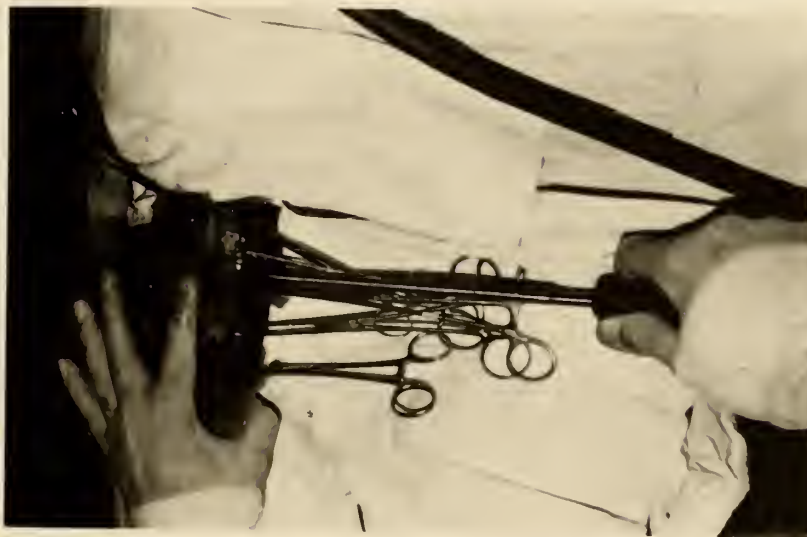
Picture 15 The position of the C-clamp for drilling the distal screw hole

Notice that the regular ASIF hexagonal screw driver is in the proximal screw to aid in identification of angles for screw placement.

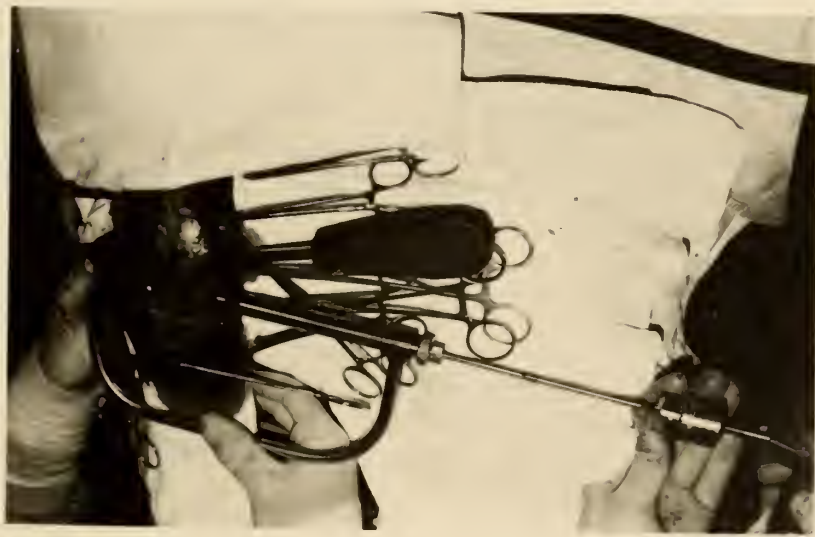
Picture
13



Picture
14



Picture
15



Picture 16 Inserting the distal screw through
the C-clamp drill guide for place-
ment in the bone

Picture 17 The lateral view of the cadaver
specimen of an accessory carpal
bone osteotomy and repair

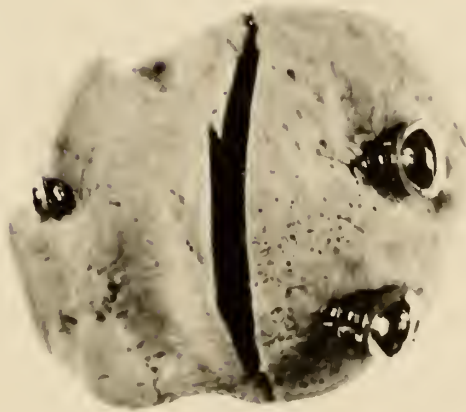
Picture 18 A view of the position of the screws
in the palmar and dorsal fragments

Notice the crack in this specimen.
This is to emphasize the importance of
a good purchase in the palmar fracture
fragment.

Picture 16



Picture 17



Picture 18



Picture 19 A lateral to medial radiograph of the repaired accessory carpal bone fracture in horse #6

Notice the line of the osteotomy.
This is evident even after 90 days.

Picture 20 The support bandage used for the first ten postoperative days

Picture 21 The pens and run-in sheds that the animals were confined in for the last five months of the experiment

Picture 19



Picture 20



Picture 21



- Picture 22 (left) The 180 day lateral to medial radiograph of horse #2 (Group I) showing a distinct vertical fracture line
- Picture 23(right) The 180 day proximal to distal carpal radiograph of horse #2. A distinct fracture line is present. An extensive lateral periosteal callus is also discernible.
- Picture 24 Histopathology of the fracture of horse #2. Islands of cartilage and osteoid border a line of mature fibrous connective tissue.
- Picture 25 Fibrocartilagenous nonunion of the fracture of horse #2. There is loosely woven bone and osteoid on the margin of fibrous connective tissue.

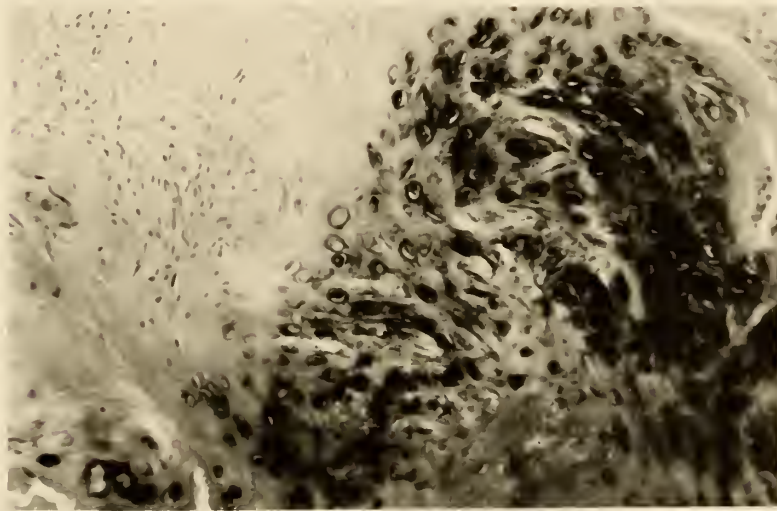


Picture 22

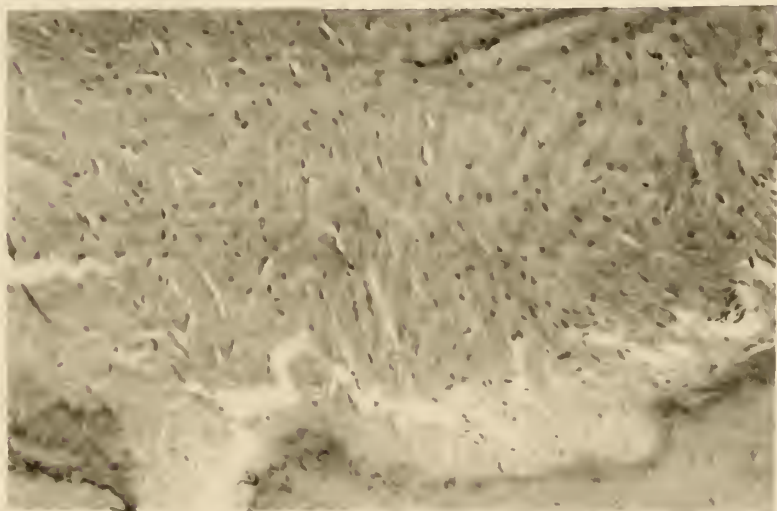


Picture 23

Picture
24



Picture
25



- Picture 26 The gross necropsy section of a fibrocartilagenous nonunion of the accessory carpal bone of horse #7 (Group I)
- Picture 27 The gross section of horse #7 showing the scar present in the carpal canal opposite the osteotomy site
- There were no adhesions or other lesions present on any other structures in the carpal canal.
- Picture 28 A lateral to medial 180 day radiograph of horse #7
- This shows the distinct vertical fracture line in the accessory carpal bone.



Picture 26



Picture 28



Picture 27

Picture 29

The medial to lateral 90 day radiograph of horse #1 (Group II)

Notice the difference in length of the proximal and distal screws. The fracture line is no longer evident.

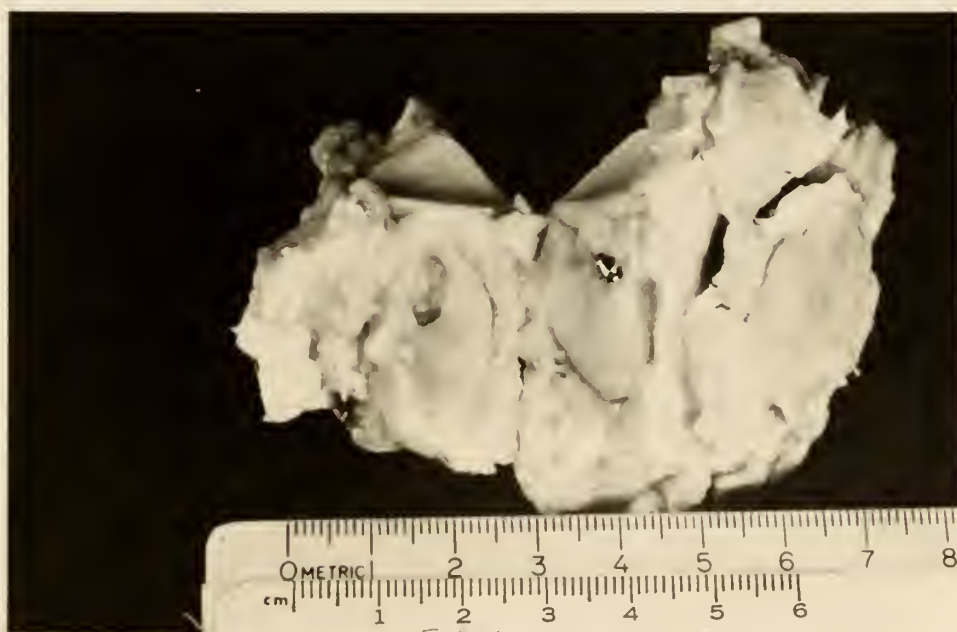
Picture 30

The necropsy specimen of horse #1 (Group II).

Notice the tip of the distal screw protruding through the distal articular facet of the accessory carpal bone. There is a defect in the articular cartilage of the ulnar carpal bone to accommodate the screw tip. This did not cause any lameness even when this horse was ridden.



Picture 29



Picture 30

Picture 31

A proximal to distal radiograph showing the carpus of horse #3 with the C-clamp in place at necropsy.

Notice the poor purchase of the dorsal fragment by the one short screw.

Picture 32

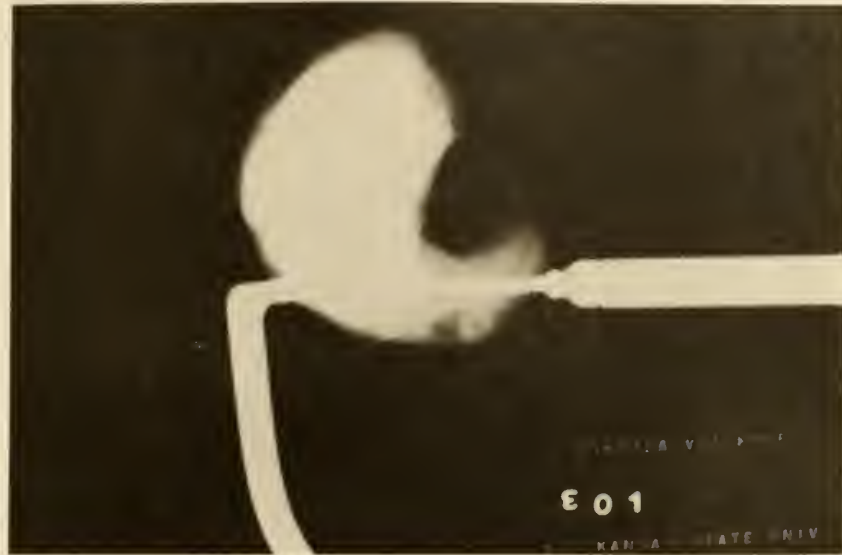
A lateral to medial operative radiograph of horse #3. The small size of the accessory carpal bone made the surgery difficult and precluded the use of two screws.

Picture 33

A cross section of the carpus of horse #3 at necropsy

Notice the nice placement of the screw in the median plane. There is a moderate amount of lateral periosteal callus present.

Picture
31



Picture 32



Picture
33



Picture 34 (left) A 30 day medial to lateral radiograph of the carpus of horse #4 (Group II).

Notice the dorsal proximal fragment and the distraction of the proximal fracture line. There is a slight amount of bony lysis around the proximal screw threads of this infected fracture.

Picture 35 (right) Lateral to medial 90 day radiograph of horse #4

The proximal screw has been removed and the fracture line is beginning to fill in.

Picture 36 A cross section of the carpus of horse #4

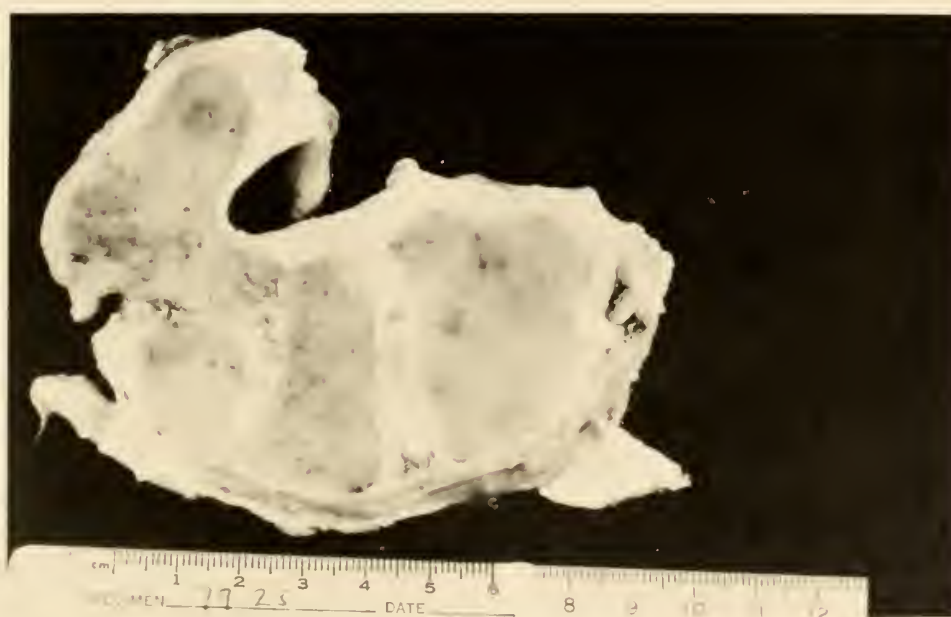
The fracture has healed but a large lateral periosteal callus is present.



Picture 34



Picture 35



Picture 36

Picture 37 Lateral to medial 30 day radiograph of the carpus of horse #9 (Group III)

Notice the screw length is adequate for a good purchase in the dorsal fragment. A osteotomy line is still present in the proximal aspect of the bone.

Picture 38 A proximal to distal radiograph of cross sections of the accessory carpal bone of horse #9

Notice the position of the screws in the median plane. The fracture is healed with minimal lateral periosteal callus.

Picture 39 A gross cross sectional view of the healed accessory carpal bone of horse #8 (Group III)

The screw threads can be seen on this section. There is a minimum of lateral periosteal callus.



Picture 37



Picture 38



Picture 39

A P P E N D I X

APPENDIX LITERATURE REVIEW

The classical theory of bone healing has dramatically changed in the past few years. With the development of aseptic surgery, uniform instrumentation and computerized case follow-up, orthopedic surgery has moved into a new era.

Studies by Ham (1930); Krompecher (1937); Pauwels (1940); Nicole (1945); Charnley (1948); Eggers, et. al. (1949); Hicks (1958); Bassett, et. al. (1961); Rhineland, et. al. (1962, 1968); the group of Muller, Allgower, Willenegger and Schenk (1963, 1969); Segmuller (1966); and Rittman and Perren (1974) have stimulated study of the repair process of bone. The experimental work of Krompecher, Bassett, Schenk and others have substantiated observations (Danis 1947; Muller, Allgower, Willenegger 1963) on the healing of osseous lesions and have stimulated further thoughts on current therapeutic methods.

The purpose of this review is to present current concepts of bone healing, internal fixation with lag screws and tetracycline labeling of bone.

Ideal healing of any tissue is by regeneration. Bone has been thought to heal by callus formation. Presently, this concept has been shown to be true only for the first stage of healing in an unstable fracture. The first stage stabilizes the fracture with a large quantity of poor quality bony matrix. A neutral zone of osteogenesis forms in the cortex of the bone after it has been stabilized. The neutral zone occurs without intermediary tissue,

i. e. only on the basis of a pronounced capillary network (Segmuller 1966). New and primarily constructive osteons are found on the edges of the capillary network. Krompecher (1937) postulated three forms of embryonic osteogenesis (intra-membraneous, endochondral and an angiogenic form) with occurrence depending on the type of intermediary tissue.

Schenk and Wellenegger (1963) noted the osteogenic unit to be a capillary sprout surrounded by perivascular osteoblasts. Differentiation in bone seems to arise from so-called primitive reserve cells (osteoprogenator cells). The young cells develop either directly into osteoblasts or chondroblasts, then to osteocytes and chondrocytes which produce bone matrix. The first and largest arterioles which enter the fracture site are derived from the marrow cavity, which was found by Rhinelander, et. al. (1962) to be the major source of blood supply to the uniting callus. It was found that as time passed, the medullary circulation anastomosed at first through a uniting callus and later through large vascular channels which penetrated the cortex. Callus in the adult arises from granulation tissue rich in cells.

In the fully mature skeleton, the periosteum is in a resting state and has little capacity for rapid cellular regeneration. Mild trauma will produce an active zone of cell proliferation and differentiation at the site of injury.

Bassett (1962) subjected osteoblast cultures to different conditions. He was able to demonstrate that when embryonic osteoblasts were subjected to compaction forces, bone formation would

result. When the same cell types were subjected to stretching forces, a fibrous tendon-like tissue was formed. He further demonstrated that changing the oxygen tension in the medium affected the cells. Embryonic osteoblasts, in vitro, form bone under constant hydrostatic pressure with the addition of oxygen. Lack of oxygen will lead to cartilage formation. Tension in the presence of oxygen leads to the formation of fibrous tissue. Nicole (1945) demonstrated that bone subjected to shearing forces would form fibrous connective tissue between the fragments. This connective tissue when subjected to compression, changed to cartilage and then to chondrogenic bone. When compression was combined with tension forces, fibrous callus formed.

The work of Schenk and Willenegger (1963), Segmuller (1966) and Hutzscheneuter, et. al. (1973), has shown that with adequate stabilization of the severed diaphysis, the periosteum and periosteal tissue show only minimal reaction and hence little radiological evidence of callus formation. They also demonstrated that fissures in human bone heal by direct intracanalicular new bone formation. The absence of visible periosteal callus is one of the predominant and reproducible features characterized by the repair process of adequately reduced and stabilized osteotomies in dogs and long bone fractures in man. This regenerative potential of mature cortical bone in a mechanically neutral zone has become known as primary Haversian bone healing. It appears to be identical to the angiogenic osteogenesis in the embryonic bone in areas free of mechanical stress, as demonstrated by Krompfecher (1937),

The occurrence of primary bone healing after internal fixation was suspected by Lane (1914) on the basis of radiological findings. Danis (1947) emphasized the absence of callus formation after plating.

Experimental work by Bagby (1958) demonstrated the appearance of what is now called gap healing. Gap healing takes place in areas where a stable gap is maintained. The gap is filled by lamellar bone with an orientation that is transverse to the long axis of the bone. In a secondary stage, this bone will be remodeled to conform to the long axis of the bone.

Contact healing can take place only in the presence of absolute stability. Radiologically, the fracture gap will disappear and there will be no significant callus formation. Histologically, if a stable contacting area exists, Haversian osteons cross the fracture gap from one fragment to the other. This link leads to a very intimate bridging of the fracture area described by Perren, et. al. (1969).

Much of the information on bone healing has been obtained from work with bone fluorescents. The observation of Milch, et. al. (1957) that tetracycline becomes localized in areas of new bone formation, was the first breakthrough. Harris, et. al. (1960) showed tetracycline to be a suitable marker whereby the rate of bone formation could be measured. Skinner and Nalbandian (1975) have reviewed the mineral tissue dynamics, chemistry and fluorescent and nonfluorescent effects of tetracycline in bone. They have suggested a dosage of 20 mg/Kg of body weight per day for three to

six days in order to obtain sharp tetracycline fluorescent labels in adult animals.

The development of internal fixation of fractures occurred as surgeons searched for improved methods of stabilizing fractures. Most stabilization methods imply reduction and retention of the fragments, but few neutralize the fracture zone continuously during the long process of complete consolidation. The disadvantages of the internal fixation devices such as intermedullary nails and circlage wire is that the primary goal of operative stabilization, namely primary bone healing, is not achieved. It may in fact, be delayed.

Lambotte (1913) considered the screw to be the basic element for stabilization of fractures and osteotomies. Wagner (1962, 1963) showed that most of the screws in use during the time of his experiments, loosened after several weeks. It was found that ordinary screws did not provide sufficient holding power in the fibrous tissue that replaces necrotic bone, even when little mechanical stress was placed on them. This observation led the AO group of Muller, Allgower and Willenegger (1963) to develop the ASIF screw. This screw was extensively tested by Wagner (1962). He showed that bony necrosis can be prevented by using the ASIF screw. The profile of the ASIF screw takes into account the structure of the compact substance of bone. The lines of stress fall almost perpendicular on the bone lying between the screw threads. Shearing forces are thereby avoided. A tap is used to form a bed for the screw thread in the bone, thus better seating of the screw

is provided and a decrease occurs in the amount of heat produced. Wagner (1962) was unable to demonstrate any fibrous tissue formation in the bed surrounding the threads, following accurate introduction of the screw. Vital bone lamellae formed directly adjacent to the implant (Schenk 1977).

Charnley (1948) demonstrated that compression in cancellous bone did not lead to necrosis but allowed for rapid and undisturbed bone remodeling. Wagner (1963) reported that compact bone compression would not lead to tissue destruction as long as the compression was constant and even.

Certain principles of lag screw fixation have been advocated by Segmuller (1966):

- 1) Screws must not be parallel to each other.
- 2) Several screws are best so that the entire fracture zone is put under compression.
- 3) Evenly distributed compression is possible only if the fracture has been anatomically reduced.
- 4) After proper fixation, nonweight bearing joint movement should be started as soon as possible.

From a technical standpoint, the relationship between compression and stability in ridged internal fixation is clear; local pressure production is the basis for any stabilization method utilizing an implant (except when the implant is glued to the bone), since transmission of forces is only possible through local pressure areas between the bone. Micromotion has been shown to contribute to bone resorption (earlier claimed to be bone necrosis),

secondary bone and external callus formation (Perren, et. al. 1969).

Persistent instability at the area of a fracture has been shown to lead to fibrocartilagenous delayed union. This delayed union is characterized by Schenk (1977):

- 1) Persistence of interfragmentary fibrocartilage
- 2) Inhibition of fibrocartilage mineralization
- 3) Inhibition of cartilage resorption and vascular ingrowth
- 4) Restriction of bone remodeling to the fragment ends in sclerosis

Clinical experience has shown that these reactive nonunions heal rapidly after rigid fixation and without removal of the interfragmentary tissue. The healing process has been shown to take place in four stages (Schenk 1977):

- 1) Mineralization of interfragmentary fibrocartilage
- 2) Substitution of mineralized fibrocartilage by woven bone
- 3) Substitution of woven bone by mature cancellous bone
- 4) Reconstruction of cortical compact bone

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INDIVIDUAL ANIMAL RESULTS

Equine No. 1 - Tatoo #E01-1 - Group II

The accessory carpal bone osteotomy surgery went well with no postoperative discomfort or complications. The bone was repaired sixteen days later with two ASIF cortical bone screws. The proximal screw was 38 mm in length. The distal screw was 44 mm long. The screws appeared to be well placed in the bone with good compression and stabilization. There was no crepitation when the carpus was flexed after the skin was closed. The horse recovered well from surgery and had an uneventful thirty days of postoperative stall confinement.

Lameness Evaluation

The horse showed no signs of lameness prior to the experiment. Sixty days post fracture repair, the animal was not lame. This horse remained free from all signs of lameness for the duration of the six month experiment. This horse was ridden by three veterinary students one hour per day, five days per week, during the last sixty days of the experiment.

Radiographical Evaluation

The operative films of this horse showed that the distal screw was into or possibly just penetrating the dorsal cortex of the accessory carpal bone. The screw placement and fracture reduction were good. The thirty day follow-up film showed a slight amount of roughening of the bone at the proximal fracture edges. The

fracture line appeared slightly more lytic than when seen on the operative films. The sixty day follow-up films revealed a healed fracture with almost no proximal or lateral callous formation. The radiographic evaluations for the next four months showed that the fracture line was no longer evident.

Gross Pathological Examination

Examination of the carpus revealed a stable accessory carpal bone. There was a 10 by 3 mm roughened, pink area on the synovial membranes of the carpal canal just opposite the osteotomy site. There was no crepitation when the carpus was flexed. The tip of the distal screw was protruding 2 to 4 mm through the distal articular facet of the accessory carpal bone. The screw had formed a 2 by 4 mm, 2 mm deep, cup in the ulnar carpal bone to receive the screw head without interference with any osseous structure. Cross sections of the accessory carpal bone showed a healed fracture with approximately a 1 to 2 mm wide, 4 mm long, callus present on the lateral aspect of the bone in the area just posterior to the groove for the long tendon of the ulnaris lateralis. The screws were well seated in the middle of the bone.

Tetracycline Label

The cancellous bone dorsal and palmar to a very faint osteotomy line across the entire bone, had taken up the tetracycline label.

Histopathological Examination

This fracture healed with a bony union. There were Haversian

systems present throughout the section. There was an intermingling of compact and cancellous bone with mild remodeling.

Equine No. 2 - Tatoo #E01-2 - Group I

The accessory carpal bone osteotomy surgery was uneventful. The bone was not repaired on this horse. The horse recovered from surgery with no complications and spent a comfortable thirty days in stall confinement.

Lameness Evaluation

The horse was free from lameness in the front end at the start of the experiment. This horse did have a slightly shortened stride in the left rear leg when observed at a trot. Sixty days post fracture, the horse was lame in the left front leg at a walk and severely lame at a trot. The animal showed signs of pain when the carpus was flexed. The animal was at times three legged and would hop while carrying the left front limb. The ninety day lameness examination found the horse to be slightly lame at a walk and severely lame at a trot. At 120 days, the horse was moderately lame at a trot. This lameness was exaggerated after the carpus had been flexed. The lameness improved and by 150 days, the animal was slightly lame at a trot in a straight line. This lameness became quite exaggerated after the carpus was flexed. The gait had not improved at the termination of the experiment. The lateral aspect of the accessory carpal bone became noticeably enlarged over the six month course of the experiment. Crepitation could not be illicited from the area upon palpation.

Radiographical Evaluation

The operative films showed a clean vertical osteotomy, Thirty

days post osteotomy, the line was more lytic. There was a slight shadow of lateral callus present at this time. By sixty days, the osteotomy site was even more lytic and widened. There was a small amount of proximal lipping. The lateral callus was much more distinct at this time. The ninety day evaluation showed a lytic fracture gap with a slight amount of sclerosis adjacent to its edges. The proximal lip seen at sixty days was more prominent. The lateral callus was now protruding about 4 mm. The fracture had changed very little on the 120, 150 and 180 day evaluations except that the lateral callus had become larger and more organized. From the radiographs, this bone appeared to be a nonreactive nonunion from the ninety day post-osteotomy evaluation to the end of the experiment.

Gross Pathological Examination

Examination of the carpus revealed a non-stable accessory carpal bone. There was a 5 by 10 mm roughened, pink area on the synovial lining of the carpal canal adjacent to the medial surface of the osteotomy. Cross sections of the carpus revealed an accessory carpal bone that was healing with a fibrous union. There were strands of fibrous-appearing tissue loosely holding the fracture fragments together. There was white cartilagenous-appearing tissue deep to this fibrous tissue. There was an 8-10 mm wide 10 mm long, lateral callus just palmar to the groove for the long tendon of the ulnaris lateralis.

Tetracycline Label

The cancellous bone dorsal to the gapping fracture line, picked

up a large amount of label. The palmar fragment showed only faint fluorescence.

Histopathological Examination

The margins of fracture were surrounded by thinly woven immature Haversian systems and resorption cavities. Cementing lines were present between areas of old and new bone in the areas of active remodeling. Islands of immature bone were interspersed throughout the area adjacent to the fracture line. The fracture line was filled with longitudinally-directed mature fibrous connective tissue. This fracture had healed by fibrocartilagenous nonunion.

Equine No. 3 - Tatoo #E01-3 - Group II

The vertical osteotomy of the accessory carpal bone was performed and the horse recovered from anesthesia with no complications. The horse developed a transient elevated temperature after the second day of tetracycline therapy. The bone was surgically repaired fourteen days post fracture. Because of the small size of this gelding's carpus, the C-clamp did not fit snugly in position. This made screw placement very difficult. Several holes were drilled in the proximal aspect of the bone before proper placement of a 34 mm long screw was achieved. The operative radiographs revealed that the screw was near the center of the bone in the proximal to distal plane. An unsuccessful attempt was made to place a screw in the distal portion of the bone. It was decided at this time not to place a second screw. The one screw seemed to stabilize the fragments when manipulation was attempted. The horse recovered from anesthesia and spent a comfortable thirty days of stall confinement. This horse developed a habronema infestation of the suture line two weeks postoperative. The infestation responded to topical therapy in about thirty days.

Lameness Evaluation

This horse showed no signs of lameness at the beginning of the experiment. Sixty days post fracture repair, the horse was moderately lame at a trot. This lameness slowly became less noticeable. By the 150 day evaluation, the gelding was not lame. At the 180 day evaluation, two of the three evaluators¹ thought that this horse

¹ Doctors K. J. Easley and J. E. Schneider

was slightly favoring the left front leg when trotted after the carpus had been flexed.

Radiographical Evaluation

The one screw used to reduce and stabilize this bone was thought to be inadequate. The screw had only about 4-6 mm of purchase in the dorsal fragment. The fracture had been reduced well but the one screw was not considered to be adequate to stabilize the fracture. The fracture line was more prominent by thirty days post repair. On the sixty day evaluation, there was a proximal bridging callus present. The bone appeared healed by the 150 day evaluation.

Gross Pathological Examination

Examination of the carpus revealed a stable accessory carpal bone. There was a marked 5 mm wide lateral callus present in the area of the groove for the long tendon of the ulnaris lateralis. There was no roughness or discoloration in the carpal canal and the flexor tendons appeared normal. Cross sections of the accessory carpal bone revealed a healed fracture. The screw was well placed in the bone but only 6 mm crossed the fracture line. The screw did not purchase in the dorsal cortex of the bone. There was a 10 mm wide 15 mm long lateral callus in the area just palmar to the lateral groove.

Tetracycline Label

The cancellous bone palmar and dorsal to a 1-2 mm fracture line,

had taken up label. The fracture line crossed both the medial and lateral cortex of the bone.

Histopathological Examination

This fracture healed by bony union. Active bone was present throughout the section. Mature and immature Haversian systems were intermingled throughout the bone. In the area of the fracture and the periosteal callus, resorption cavities and cementing lines were more numerous. There was a large lateral external callus that contained numerous islands of cartilage and osteoid.

Equine No. 4 - Tattoo #E014 - Group II

When the osteotomy was performed, a 10 by 10 mm chip was broken off the proximal aspect of the dorsal fragment. The osteotomy surgery went well and the gelding made an uneventful recovery. The horse went off feed and became depressed after the second day of tetracycline therapy. This condition was transient and the horse soon improved. The bone was repaired on the 19th day post fracture. When the preoperative prep bandage was removed on the surgery table, it was found that several skin sutures had been left in the area. These were removed and several drops of purulent material were noticed. The area was completely presurgically prepared. The fracture was repaired with two 40 mm long screws. The screws were well seated in the bone and good stability was achieved. There was not good reduction in the proximal aspect of the fracture line where the 10 by 10 mm chip had broken off the proximal aspect of the dorsal fragment. The animal recovered from surgery and had a comfortable postoperative convalescent period. On the 11th postoperative day, the leg was slightly swollen at the carpus but not hot or painful. By the 28th day, a draining tract had developed in the dorsal aspect of the suture line. A culture of the tract harvested a mixed growth of Beta hemolytic Streptococcus, Actinobaccilus sp., and Staphylococcus Aureus. The tract was debrided and irrigated with a nitrofurazone¹ and saline solution. The leg was placed in a sweat which consisted of nitrofurazone, magnesium sulfate and methysalicylate dressing covered

¹ Furacin, Norwich-Eaton Pharmaceuticals, Norwich, New York

with plastic. The dressing was changed daily for ten days. The animal was treated for a ten day period with 30 ml of penicillin and dihydrostreptomycin². The leg appeared to respond to therapy and the animal was not painful on the limb. Radiographs taken on the 10th and 30th postoperative days did not show signs of an infected implant.

Radiographs on the 45th, 60th and 90th days, showed evidence of lysis around the proximal screw and it was loosening. The proximal screw was removed on the 90th day under local anesthesia through a stab incision in the skin.

Lameness Evaluation

This gelding was not lame at the beginning of the experiment. Sixty days post osteotomy repair, the horse was moderately lame at a trot in a straight line but this lameness did increase after the carpus was flexed. The horse was not lame on the 120 or 150 day evaluations. On the 180 day evaluation, two of the evaluators² thought the horse was slightly lame when trotted after the carpus had been flexed. This horse was ridden by three veterinary students for the last thirty days of the experiment. The horse showed no evidence of lameness.

Radiographical Evaluation

The two screws used to reduce and stabilize this fracture were adequate. The fracture was not reduced well at the proximal aspect. The thirty day radiograph showed an extensive amount of proximal

¹ Combiotic, Pfizer Inc., New York, New York
² Doctors K. J. Easley and J. E. Schneider

and lateral reaction on the bone. The fracture line was not healing at this time. The sixty day film showed an area of lysis around the threads of the proximal screw. At that time, the fracture was beginning to show signs of healing but there was an extensive amount of lateral and proximal callus formation. The ninety day film showed the proximal screw to be loosening and backing out. The screw tract was infected but the bone appeared to be stabilized and healing. By 120 days, the proximal screw was removed and the bone looked almost healed. The fracture was healed radiographically by 150 days.

Gross Pathological Examination

The accessory carpal bone appeared to be stable. There were no lesions observed in the carpal canal. Cross sections of the bone revealed a healed fracture. There was an 8 mm wide, 4 mm long callus just posterior to the lateral groove. The proximal screw tract appeared to have filled in with cancellous bone. The distal screw was well seated in the bone with the head covered by calcified tissue.

Tetracycline Label

Label was taken up by the cancellous bone on the palmar aspect of the fracture line. A distinct fracture line was not well outlined on this bone.

Histopathological Examination

This fracture healed by bony union. The fracture line was healed with mature Haversian systems present throughout the section.

The area where the proximal screw was removed contained small islands of cartilage and areas of active bone remodeling. There were no inflammatory cells present in this area. The periosteal callus margins consisted of Sharpy's fibers intergrating with islands of cartilage and osteoid.

Equine No. 5 - Tatoo #E01-5 - Group I

The osteotomy was performed and the animal recovered from surgery without incident. No complications were encountered. The bone was not repaired.

Lameness Evaluation

At the beginning of the experiment, this animal showed no signs of lameness. The gelding was severely lame at sixty days post fracture. The lameness had improved slightly by the ninety day evaluation. At that time, the horse was bearing weight on the limb well but was moderately lame at a trot. The lameness had not improved by the 120 day evaluation. By 150 days, the lameness was somewhat improved with the horse slightly lame at a trot. This lameness was exaggerated after flexing the carpus. The animal did not improve from this point to the termination of the experiment.

Radiographical Evaluation

The thirty and sixty day post osteotomy radiographs demonstrated a widening of the fracture gap. There was a considerable amount of proximal and lateral callus present. The fracture appeared to be healing on the 120 day films and the lateral callus was more evident. The osteotomy appeared to be bridged by the lateral callus and healing on the 150 day radiograph. By 180 days, the fracture appeared healed with an extensive bridging callus.

Gross Pathological Examination

The accessory carpal bone appeared stable. There was an

extensive lateral bony callus. The carpal canal and flexor tendons appeared normal. Cross sections of the accessory carpal bone revealed a healed fracture. There was a 10 mm long, 10 mm thick lateral callus just posterior to the lateral groove.

Tetracycline Label

Label was present on the cancellous bone, palmar and dorsal to a 5 mm thick healed osteotomy line,

Histopathological Examination

This fracture healed by delayed bony union. The fracture line was crossed by osteons in several areas. There were several large islands of fibrous connective tissue in the center of the section. There was active bone remodeling adjacent to the fracture line. Several small islands of cartilage were present near the fracture line, surrounded by thin, immature trabecular bone.

Equine No. 6 - Tattoo E01-7 - Group III

The surgical osteotomy was performed and repaired with a 34 mm long proximal screw and a 36 mm long distal screw. The screws were adequately placed in the bone. The screws appeared to be well seated into the dorsal fragment but were 2 to 4 mm short of reaching the dorsal cortex. The fracture was stable but the fracture line was not compressed well. The horse recovered from the surgery and spent an uncomplicated thirty days of stall confinement.

Lameness Evaluation

The horse was not lame at a walk or trot on the 60, 90 or 120 day evaluations. After the carpus was held in the flexed position for two minutes, the horse did slightly favor the left front leg. After the 120 day evaluation, the radiocarpal joint was anesthetized with 20 ml of 2% carbocaine. The horse appeared sound after this block was performed. This degree of lameness did not improve until 150 days post surgery. At that time, the horse appeared sound and remained so throughout the remainder of the experiment.

Radiographical Evaluation

The fracture line appeared to become wider and more prominent during the first sixty days post repair. There was very little callus present on the thirty or sixty day films. The osteotomy looked as though it was beginning to heal by the ninety day film. The fracture line slowly filled in over the next sixty days and the fracture appeared to be healed completely by the 150 day

radiograph. There never appeared to be very much proximal or lateral callus present on any of the films.

Gross Pathological Examination

The carpus was stable and there was very little lateral callus present. There was a 5 by 5 mm roughened, pink scar present in the carpal canal, opposite the osteotomy site. Cross sections of the accessory carpal bone revealed a healed fracture. There was very little (less than 3 mm wide and 2 mm long) lateral callus present just posterior to the lateral groove. The two screws were well placed in the bone but 2 to 4 mm short of contacting the dorsal cortex.

Tetracycline Label

The label was taken up by the bone dorsal and palmar to a 1 mm wide fracture line.

Histopathological Examination

This fracture healed by bony union. Active Haversian systems with cementing lines adjacent to areas of mild osteoclastic activity were present throughout the section. There was a moderately vascular external lateral callus present.

Equine No. 7 - Tatoo E01-9 - Group I

The osteotomy surgery went well and the mare recovered from the surgery without complications.

Lameness Evaluation

This mare was slightly lame at a trot at sixty days post surgery. The lameness did increase after the carpus was flexed. By ninety days post surgery, the mare was lame at a walk and severely lame at a trot. She remained so until 150 days. Crepitation was palpated when the accessory carpal bone area was manipulated at 120 days post fracture. By 150 days, the horse was walking well but lame at a trot. No crepitation could be elicited from the area at that time. At the termination of the experiment, the mare was lame at a walk and severely lame at a trot. This lameness did improve after the ulnar, median and musculocutaneous nerves had been blocked out above the carpal joint.

Radiographical Evaluation

The fracture line became progressively more prominent at each evaluation until 150 days post surgery. There was an active line of sclerosis both palmar and dorsal to the fracture line at ninety days post surgery. At that time, there was an extensive lateral and proximal bridging callus present. The fracture line was less evident by the termination of the experiment. It appeared as though this fracture was healing with a fibrous nonunion or at least a fibrocartilagenous delayed union.

Gross Pathological Examination

The accessory carpal bone appeared stable. There was a large lateral bony callus. The carpal canal had a 2 by 5 mm pink, roughened area on the synovial membranes opposite the osteotomy site. Cross sections of the accessory carpal bone revealed a non-healed fracture. There were strands of fibrous tissue and white cartilagenous-appearing tissue weakly stabilizing the fracture line. There was a 5 by 5 mm white, fibrous area in the cancellous portion of the bone at the osteotomy site.

Tetracycline Label

There was very little uptake of label in the cancellous portion of the bone.

Histopathological Examination

This fracture healed by fibrocartilagenous nonunion. Some margins of the fracture line were bordered by ridges and grooves covered by osteoblasts. The rough bone surface intermingled with mature fibrous connective tissue that filled the fracture gap. There were areas of immature bone bordered by a zone of young proliferating cartilage that blended with the fibrous connective tissue at the fracture line. The entire section of bone had active remodeling on both sides of the fracture line. There was a large vascular external callus present on the lateral surface of the bone.

Equine No. 8 - Tatoo #E02-0 - Group III

The osteotomy surgery proceeded without complications. The bone was repaired with a 34 mm screw proximally and a 42 mm screw, distally. Both screws appeared to be 4 mm short of reaching the dorsal cortex of the bone. The screws were well placed and reduction of the fracture line was good. The mare recovered from surgery and spent an uneventful thirty days in stall confinement.

Lameness Evaluation

This mare had contracted heels and navicular disease. A palmar digital nerve block was performed before each lameness evaluation. This nerve block made the horse comfortable for the preoperative evaluation and she showed no lameness.

The mare was sound at 60 days post osteotomy and repair and remained sound for the remainder of the study.

Radiographical Evaluation

The osteotomy line was faintly present on the thirty day film. There was a halo of sclerosis present at the dorsal and palmar margins of the fracture line at thirty days post surgery. There was no evidence of any callus formation. By sixty days post fracture, the bone appeared to be healed with very little external callus.

Gross Pathological Examination

The carpus was stable and there was no lateral callus present. Cross sections of the accessory carpal bone revealed a healed

fracture. There was a very slight amount of lateral callus present. The screws were well placed and within 4 mm of the dorsal cortex of the bone.

Tetracycline Label

The cancellous portion of the bone palmar and dorsal to a 1 mm wide line, was present. The fracture line appeared to cross the medial cortex at a dorsal angle, breaking through just dorsal to the carpal canal.

Histopathological Examination

This fracture healed by bony union. The fracture line was healed and moderate bone remodeling was present throughout the section of the bone.

Equine No. 9 - Tattoo #D-12087 - Group III

The osteotomy was performed without incident. The bone was repaired with two 46 mm long screws. The screws were well seated in the bone and reduction of the osteotomy site was adequate. At the proximal aspect, there was a 2 to 4 mm gap in the fracture line. Both screws appeared to purchase in the dorsal cortex of the bone. The mare recovered from surgery uneventfully. She showed a moderate amount of postoperative pain in the leg for the first five days, post surgery. This pain was transient and she had an uneventful thirty days of stall confinement.

Lameness Evaluation

The mare was not lame at any of the evaluations. She was ridden periodically from the 120th postoperative day until the termination of the experiment. At no time did she show signs of any discomfort of the limb.

Radiological Evaluation

The fracture line was more prominent on the thirty day and even more so on the 60 day evaluation. The proximal gap was widened and surrounded by a sclerotic zone. The proximal aspect of the osteotomy was healing and the distal aspect was healed by the 90th postoperative day. The fracture appeared healed with a small amount of proximal bridging callus on the 120 day radiograph. The 180 day film revealed a healed fracture with almost no external callus formation.

Gross Pathological Examination

The carpus was stable and there was no external callus, grossly. The distal screw was seen just flush with the distal articular facet. There was no lesion on the ulnar carpal bone or its articular cartilage. The carpal canal had a 2 by 6 mm roughened, pink area on the synovial lining just opposite the osteotomy site. The flexor tendons appeared normal. Cross sections of the accessory carpal bone revealed a healed fracture. There was very little lateral callus present.

Tetracycline Label

The cancellous bone proximal and distal to a 1 to 2 mm wide line, had been labeled. The osteotomy line was seen bridging lateral and medial cortices of the bone.

Histopathological Examination

This fracture healed by bony union. There were mature Haversian systems with a mild amount of remodeling, exemplified by cementing lines, indicating a healed fracture line.

EVALUATION OF THE SURGICAL REPAIR OF
EQUINE ACCESSORY CARPAL (PISIFORM) BONE FRACTURES

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ABSTRACT

Accessory carpal (pisiform) bone fractures in the athletic horse have been a difficult problem for the surgeon. Veterinarians have treated this condition conservatively with few horses returning to athletic competition after prolonged periods of rest.

Internal fixation of fractures has made great progress in the past decade. Equine surgeons have had difficulty using this method of fixation to repair accessory carpal bone fractures because of inherent difficulty in placing a straight screw in a curved bone.

In this study, a group of horses had osteotomies performed to simulate accessory carpal bone fractures. With the aid of a large C-clamp, screw fixation was performed on six of nine horses. Three control horses were treated conservatively.

The three control horses whose fractures were not repaired, remained clinically lame throughout the six month experiment period. The accessory carpal bones did not heal on two of these three horses. The other horse did heal with a large callus, only after a period of five months.

The six horses that had their fractured accessory carpal bones repaired, were free from lameness at 150 days post fracture. Radiographic and pathological results correlated well with the clinical findings.

From this project, a method of consistently reducing and stabilizing horizontal accessory carpal bone fractures with cortical bone screws was developed. The results of clinical, radiographic

and pathological evaluations showed surgical repair to be superior to a prolonged period of rest in the treatment of accessory carpal bone fractures.

