SURGICAL ARTHRODESIS OF THE DISTAL INTERPHALANGEAL JOINT IN

A HORSE

by

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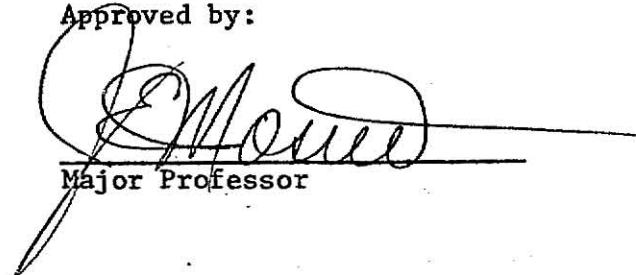submitted in partial fulfillment of the

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SURGICAL ARTHRODESIS OF THE DISTAL INTERPHALANGEAL JOINT

IN A HORSE

INTRODUCTION

Osteoarthritis of the distal interphalangeal joint (low articular ringbone, low true ringbone, pyramidal disease) is a pathological condition that has been recognized in horses for many years. Veterinarians have not been successful in developing a treatment for the relief of the pain associated with this condition. In human orthopedic surgery, prior to the development of prosthetic joints, arthrodesis was a common surgical treatment for osteoarthritis. Only recently has surgical arthrodesis been a treatment for osteoarthritic joints in veterinary medicine. However it has been recognized that ankylosis of the distal interphalangeal joint will occur in some equine cases of osteoarthritis of this joint. With this ankylosis, the painful lameness disappears.[11] Thus it would seem feasible that surgical arthrodesis of the distal interphalangeal joint could be a treatment for osteoarthritis of this joint.

REVIEW OF THE LITERATURE

The etiology of osteoarthritis of the distal interphalangeal joint in many cases is obscure. Frank[5] stated that most ringbones originate as a periostitis and ostitis on the shaft of the bone and, with the production of bone, had the potential of extending to and interfering with the movement of the joint. Dollar[11] stated that most cases of osteoarthritis of the distal interphalangeal joint are a result of direct trauma to that portion of the limb. A hereditary predisposition has been proposed for high ringbone (osteoarthritis of the proximal interphalangeal joint). Haakenstad[9] demonstrated that the sagittal ridge on the proximal phalanx was poorly developed

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in affected horses, which allowed abnormal joint movement. Poor conformation, such as a base-wide or base-narrow stance[2], and uneven weight distribution due to an uneven foot or improper shoeing[11] have been associated with an increased incidence. The probable pathogenesis is an increased concussion on certain portions of the joint. Upright pasterns, producing increased concussion on the entire limb, have been associated with osteoarthritis of the distal inter-phalangeal joint[2]. A radiographic review[3] of 85 cases revealed that 33 developed with an insidious onset and with no known cause at the time of examination. A high proportion of these cases (24/33) had other pathological lesions that are also associated with increased concussion to the distal limb (navicular disease, sidebone, high ringbone, pedal osteitis). Fractures of the extensor process of the distal phalanx, comminuted middle phalanx frac-tures, and other fractures of the distal phalanx extending into the distal interphalangeal joint will all result in osteoarthritis of some degree. Adams[2] stated that osteoarthritis of the distal interphalangeal joint is fre-quently secondary to periostitis produced by pulling of the periosteum at the attachment of the collateral ligaments, the joint capsule, or the common or long digital extensor tendons as they attach to the extensor process of the distal phalanx. Other etiologies observed are: as a sequel to navel infec-tion[10] and other infectious arthritides, using a young horse too hard too soon or young animals that are rachitic[10], injuries to the periosteum from wire cuts[5], untreated infections of the periosteum[3], pulling of the joint capsule from either subluxation of the joint following damage to the deep digital flexor tendon or rotation of the distal phalanx due to chronic laminitis[3], and injuries to the hoof such as hoof cracks and sole penetrations[3].

The clinical signs of osteoarthritis of the distal interphalangeal joint have been characterized. Dollar[11] pointed out that in contrast to high

ringbone, where many of the periarticular lesions would be asymptomatic after the acute phase had passed, the presence of any exostosis under the hoof, such as would occur with osteoarthritis of the distal interphalangeal joint, would cause lameness from the pressure. The characteristic clinical signs of this lameness have been described. Lameness is accentuated when the foot receives its greatest concussion. Lameness is more pronounced at the trot and may be more noticeable when the horse is forced to circle towards the affected limb. The foot changes shape from a U-shaped ground surface to a V-shaped ground surface[5]. The foot will gradually develop what has been termed a "buttress foot" which is a bony exostosis beneath the dorsal margin of the coronary band. In the early stages of the disease hair will be noticed standing erect on the coronary band[2]. Affected horses point the lame foot and have a shortened anterior phase of the stride. In contrast to navicular disease, however, affected horses will land on their heel.

Because there has been no modern treatment developed for this pathological condition, many of the older remedies such as blistering, thermal cautery, and neurectomies are still used. The conservative treatments of leveling an uneven foot, shoeing with a roller motion shoe to decrease the amount of motion required by the distal interphalangeal joint, and thinning the hoof wall over the exostosis[5] are still used routinely. Radiation therapy has been used, but poor results have been obtained except when all of the pathological change is periarticular[2]. Chip fractures of the extensor process are now routinely removed, and avulsion fractures of the extensor process may be reduced with ASIF[a] compression screws[2]. When articular involvement occurs there is no good treatment. Steroids provide temporary relief but may lead to further destruction of joint integrity[2]. Ankylosis of the distal interpha-

[a]ASIF - Association for the Study of Internal Fixation

langeal joint has been observed to occur in some instances of osteoarthritis of the distal interphalangeal joint. Although a mechanical lameness would remain[11], a working soundness at a walk would be achieved[5].

Recently in veterinary surgery surgical arthrodesis has become a treatment for osteoarthritic joints. The technique has been documented more commonly in small animal surgery. The elbow, carpus, stifle, and hock are among the joints that have been ankylosed by arthrodesis[7, 8, 12, 13]. The surgical principles that have been adopted to allow successful arthrodesis of these joints are the following:[12] 1) All articular cartilage and subchondral bone are removed until bleeding subchondral cancellous bone is reached. If any cartilage is left bony union may be inhibited, resulting in a delayed union or non-union. 2) The subchondral cancellous surfaces are held together by rigid internal implants. 3) Autogenous cancellous bone grafts are placed in any defects present between the two apposing bones. A small percentage of osteoblasts will survive, which will exert an osteogenic effect in the gap between the two bones. The cancellous graft serves as a scaffold for the ingrowth of vessels from both of the apposing bones. Complete bony fusion will occur earlier because the bone graft can be directly remodelled and replaced with new bone. If a defect exists between the two bones that is not filled with autogenous cancellous bone, this would first be filled with fibrous tissue. Thus the formation of a complete bony ankylosis would be delayed[15]. 4) External support is required until radiographic evidence of early fusion is seen, usually three to four weeks. Failure to achieve ankylosis have been attributed to[12]: 1) The presence of gaps between bone ends which are not packed with a graft of cancellous bone. 2) Inadequate immobilization allowing motion at the fusion site, thus causing delayed vascularization across the joint, preventing new bone production, causing loosening of the implants and lysis of the cancellous bone graft.

Because arthrodesis obviously eliminates the movement of the joint, this technique is primarily a procedure for relief of pain in joints with a wide range of motion. Thus in the equine species, to return a horse to soundness, only certain joints with a limited range of movement suit themselves to arthrodesis, except in those horses used for breeding only. Adams[1] describes a technique of arthrodesis of the distal intertarsal and tarsal-metatarsal joints as a treatment of bone spavin. This technique will result in a return to soundness. Adams[2] has also described a technique of arthrodesis of the proximal interphalangeal joint which involves surgically removing the articular cartilage, packing the joint with a cancellous bone graft from the tuber coxae, and immobilizing the limb in a plaster cast for eight weeks to achieve ankylosis. Johnson[10] used electrical currents to simulate the electrical and physical environment of a fracture. He reported success in decreasing the time of ankylosis and the size of extraarticular bony exostosis. Von Salis[14] described the use of ASIF cortical screws to aid in compression of the proximal interphalangeal joint. Because of the small range of motion of the proximal interphalangeal joint, arthrodesis of this joint will return a horse to complete soundness. Arthrodesis of the metacarpal-phalangeal joint has been described using a plate on the dorsal margin of the third metacarpal bone and proximal phalanx as a method of managing chronic or severe injuries of the fetlock[5]. It has been recognized that with time osteoarthritis of the distal interphalangeal joint may result in ankylosis of that joint and following ankylosis painful lameness may disappear[11]. Unfortunately the course that natural ankylosis follows resembles very closely the development of a delayed union. Attempts to bridge the joint where the articular cartilage is eroded are prevented because of the movement. Because these attempts at union are curtailed, an external callus is formed. Any pre-existing periarticular periostitis will enlarge in an attempt to bridge the joint. Unfortunately

the size of the external callus necessary to bridge the joint usually places a significant amount of pressure on the inner sensitive structures of the hoof. Thus it is possible to still have a painful lesion following ankylosis of the joint. In order to decrease the time required to produce ankylosis or to treat this delayed union type condition, certain rules regarding delayed unions should be followed[4]. Rigid fixation under compression should allow ankylosis to occur without massive external callus production.

MATERIALS AND METHODS

Twelve horses of both sexes were purchased from local auction markets. The horses were found to be physically healthy. No lameness conditions were present in the operated limb, the left forelimb. They ranged in age from two to twelve years and ranged in weight from 300 to 500 kilograms.

Prior to surgery the ground surface of the hoof was balanced, and the sole and frog were pared down to clean, dry, healthy tissue. Small holes, five on the medial surface and five on the lateral surface of the hoof, were drilled to a depth of two millimeters in a checkerboard fashion (Figures 3 and 4). An attempt was made to drill the proximal two holes on the lateral surface of the hoof just lateral to the distal interphalangeal joint (Figure 3). Number six lead birdshot was then placed in these ten holes in the hoof wall. Radiographs were taken at this time. The foot was placed on a block and radiographs were taken with the X-ray beam centered midway between the distal interphalangeal joint and the solar border of the distal phalanx for the lateral view (Figures 1 and 3) and centered on the solar border of the distal phalanx for the anterior-posterior view (Figures 2 and 4). The lateral view had to be directly lateral to qualify for a presurgical radiograph. Utilization of the lead birdshot markers on these radiographs enabled the location of the distal interphalangeal joint to be determined. Two lines were then drawn on the lateral view. Both lines were drawn from the point

on the middle phalanx where the two screw heads would lie (Figures 5 and 6).

This point was situated radiographically half way between the dorsal and

palmar surfaces and at the junction of the proximal and middle thirds of the

middle phalanx. The first line was drawn to parallel the dorsal surface of

the distal phalanx and to be 1.2 centimeters palmar to this surface

(Figure 5). The second line was drawn so as to arrive on the solar surface

of the distal phalanx just dorsal to the most dorsal portion of the semi-

lunar line (Figure 6). It is necessary that these lines be at least 1.9

centimeters apart as they bisect the most distal margin of the hoof to pre-

vent the second screw from hitting the first when it is being placed. With

the aid of the lead shot markers, marks were placed on the hoof in the same

location where these lines passed over the distal margin of the hoof on the

radiographs (Figure 7). Two lines were then drawn with a straight edge on

the anterior-posterior radiograph from points on both the lateral and medial

surfaces in the depression present at the junction between the proximal and

middle thirds of the middle phalanx, to the middle of the solar border of the

distal phalanx on the medial and lateral sides respectively (Figure 8). On

most horses this line also bisected the junction of the hoof wall with the

ground surface. When this occurred, two holes were drilled in the margin of

the hoof wall where the previous marks were made (Figure 9). If the lines

drawn on the anterior-posterior radiographs bisected the solar surface of the

hoof axially to the hoof wall, then these holes were drilled in the sole

axially to the marks on the hoof wall at the same distance that was present

on the radiographs. These holes acted as guide holes for the C-clamp

(Described in paper 2) and thus were drilled in the direction of the point

previously described on the opposite surface of the middle phalanx.

Forty-eight hours prior to surgery the hair was clipped up to and

including the metacarpal-phalangeal joint, and the lateral and medial

surfaces over the middle phalanx were shaved. The whole area including the entire hoof was presurgically prepared by scrubbing with organic iodine soap. A sterile bandage which was impregnated with a 25 per cent organic iodine solution was applied. A rubber boot was fashioned from an old inner tube and placed over the bandage to prevent contamination.

Prior to surgery the horse was tranquilized with acepromazine maleate (.07 mg./kg. body weight). The skin over and around the tuber coxae on the same side as the presurgically prepared limb was clipped and shaved. A mixture of three grams of sodium thiamylal in 500 milliliters of a five per cent solution of glycerol guiacolate and five per cent dextrose was used as an induction agent. Following induction, the horse was maintained on halothane anesthesia in a semiclosed system. The horse was placed on the surgery table with the lateral side of the affected limb up. The bandage was removed in a sterile manner. A sterile Esmarch bandage was applied from the hoof to the carpus (Figure 10). A pneumatic tourniquet was applied above the carpus at 500 millimeters mercury pressure. The tuber coxae was surgically prepared in a routine manner and then draped for surgery. The limb was draped in a routine manner with use of a sterile adhesive drape to cover the hoof. A nitrogen powered Stryker oscillating saw[1] with a 1/4 inch blade was used to remove a section of hoof wall one centimeter by 2.5 centimeters (Figure 11). This section approximated the angle of the joint space and was determined presurgically by the use of the lead shot markers on the presurgical radiographs. A nitrogen powered Stryker drill[1] with a 4.5 millimeter drill bit was used to loosen as much articular cartilage as possible (Figure 12). Precautions were taken to prevent excessive heat and subsequent thermal bone necrosis. A small spooned currette was used to remove as much of the dis-

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[1]Stryker Corpoartion, 420 Alcott St., Kalamazoo, Michigan 49001

lodged articular cartilage as possible. An attempt was made to currette down to hard subchondral bone.

At the same time another surgeon was collecting a cancellous bone graft. A 10 centimeter incision was made two centimeters ventral to and paralleling the most prominent portion of the tuber coxae. The subcutaneous tissues were sharply dissected down to the tuber coxae. The periosteum was incised. A periosteal elevator was used to lift the periosteum from the cortex (Figure 13). A 1/4 inch bone chisel was used to remove a section of the cortex measuring one centimeter by two centimeters (Figure 14). With a large spooned currette large chips of cancellous bone were harvested (Figure 15). These were stored on saline-soaked gauze sponges in a bowl (Figure 16). Following the harvesting the periosteum was reapposed with simple interrupted sutures of 00 polyglycolic acid. The subcutaneous tissues were reapposed with 00 polyglycolic acid but in a simple continous fashion. The skin was sutured with 00 nylon in a vertical mattress pattern. An oversew bandage was placed over the incision for protection should the horse lay on this side during the healing process (Figure 17). The cancellous graft was then packed into the joint cavity (Figure 18). A small piece of absorbable gelatin sponge was placed between the cancellous graft and the inside of the hoof wall (Figure 19).

A stab incision was made over the point on the lateral surface of the middle phalanx which has been described previously. This was determined in surgery by making measurements from the proximal palmar surface of the middle phalanx which can be easily palpated (Figure 19). This was achieved with the help of an autoclaved metal ruller (Figure 20). The C-clamp was then position- ed (Figure 21). The guide end was placed in the previously made guide hole in the opposite side of the hoof. The clamp end of the C-clamp was placed in the stab incision so that when it was tightened down it wedged in between

the lateral cartilage and the middle phalanx. As the clamp was tightened, the distal interphalangeal joint was held in extension (Figure 21). The drill guide was then placed in the C-clamp. A lengthened 4.5 millimeter drill bit was placed in the C-clamp and the length of the drill bit protruding out of the clamp was measured (Figure 22). The nitrogen powered Stryker was used to drill this hole its predetermined length. It was necessary to clean the drill bit several times to reach this length without excessive heat production. The length of the hole was determined by subtracting the length of the drill bit protruding from the C-clamp from the original length measured. The hole was tapped with a cancellous tap (Figure 23). Measurement of the length of the tap before and as the hole was being tapped ensured that the location of the eventual screw threads would be in bone with good strength (Figure 24). A cancellous screw of the appropriate length was then placed in the hole (Figure 25). All of the screw threads were in the distal phalanx when compression was achieved. The stab incision was closed with 00 nylon with horizontal mattress sutures. The limb was protected from contamination as the horse was rolled over. The horse was redraped. The second screw was placed in a like manner to the first. Radiographs were taken at this time. The distal limb was protected from contamination and the horse was rolled over so that the defect in the hoof could be repaired with hoof acrylic (Figure 26). The incision areas were wrapped with a sterile bandage.

The limb was padded with stockingette, and cast padding was placed in mid-metacarpus and over the coronary band. A cast was placed on the limb incorporating the foot and extending proximally to mid-metacarpus. The limb was held in extension as the cast was applied. Five rolls of Zoroc[1] were

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[1]Zoroc - Johnson and Johnson, 501 George St., New Brunswick, N.J. 08903

used. Once the cast was dry a piece of rubber inner tube was taped over the

end of the cast to prevent moisture from deteriorating the end of the cast.

A piece of metal 1/4 inch thick by 3 inches in width was molded to conform to

the distal end of the cast and taped in position to prevent frictional wear

on the inner tube and the end of the cast (Figure 26).

The horses were confined in separate box stalls for three weeks and the

first cast change. After that time the horses were turned out in small pens.

The horses were treated with 10,000 international units of procaine penicillin

per pound of body weight given intramuscularly twice daily and with three

grams of phenylbutazone given orally once daily. The antibiotic was given

because of the lengths of the first surgeries and was continued for ten

days postoperatively. Tetanus toxoid was given following surgery. At three

weeks postoperatively the horses were anesthetized with sodium thiamylal

and glyceral guiacolate. The cast was removed, radiographs were taken, and a

new cast was applied in a similar fashion. The next cast change depended on

the particular case. As long a time as possible was obtained from the second

cast. The third cast as well was on for varying lengths of time depending on

the particular animal. Usually this was removed with the horse standing. It

was removed with cuts along the dorsal and palmar surfaces. After radiographs

were taken it was determined whether the limb required further support with a

cast or whether a support wrap was sufficient. If a cast was required, the

old cast was taped back on the limb over the appropriate padding. Following

the removal of the last cast each horse was turned out to pasture and radio-

graphed periodically to monitor the progression of ankylosis.

RESULTS AND DISCUSSION

The radiographic results and the degree of lameness at the termination

of the study are listed in Table 1. Examples of the final radiographic

results are demonstrated in Figures 27 through 40.

Gross pathological examination revealed that none of the bone screws protruded through the dorsal or solar surfaces of the distal phalanx (Figures 41, 42, and 43). The periosteal callus coincided with that observed radiologically. With the exception of horse #3, all of the distal interphalangeal joints appeared to be rigid. At the time of post mortem examination the joint and screw canals of horse #3 were infected with Escherichia coli. The distal interphalangeal joint was surrounded with fibrous tissue, and draining tracts were present around the heads of both screws and on the lateral surface of the joint in this horse.

Histologically all twelve horses had varying stages of osseous ankylosis. The screw canals in the location of the shafts of the cancellous screws were filled with vascularized connective tissue (Figure 44). Active osteoclasts and osteoblasts were present in the bone adjacent to the fibrous tissue. The bone away from this canal was active and normal in appearance. The bone marrow next to the articular surfaces was replaced with a fine network of fibrous tissue and adipose tissue (Figure 45). The remainder of the histological findings varied with each horse and are listed in Table 2 and demonstrated in Figures 46 through 55.

Although all twelve horses were progressing towards osseous ankylosis, a delayed union was present in varying degrees in all cases. Several factors contributed to the delayed union. 1) Movement. The force applied to the distal phalanx when weight was borne on the leg exceeded the compression force produced by the cancellous screws. In four cases (horses 4, 7, 9 and 12) this was grossly obvious by dorsiflexion of the distal interphalangeal joint following surgery. In the remaining cases micromovement must be suspected as the causative factor in the production of external callus which was a uniform finding. The present method of screw placement produces a cruciate pattern. The center of this cross if not in the joint is very

close to it. Thus the compression achieved supplies little resistance to torsional forces. 2) Lysis of the cancellous graft. Inhibition of good vascularization and slight movement are probably the greatest contributing factors to the radiographic lysis of the cancellous graft. In some cases (horses 2 and 4) fibrous tissue was found to surround the graft or to dominate the tissue in the space between the middle and distal phalanges. As the postsurgical time increased this fibrous tissue appeared to convert to fibrocartilage, which would then undergo ossification. Therefore, it seems probable that any cancellous graft present in the joint would have eventually been incorporated into the bony ankylosis. In horses 3 and 8 infection contributed to destruction of the bone grafts. The method of removing the articular cartilage through a small opening in the hoof wall proved inadequate. Although the remaining articular cartilage appeared to degenerate with time, the presence of the cartilage provided a definite barrier to the revascularization of the bone graft. 3) Infection. In horses 3 and 8 infection played a primary role in the impairment of the attempt to bridge the joint space with an osseous union. It is possible that infections of lesser degrees were present in other horses and contributed at least to some extent to the delayed union. Ensuing lysis would loosen the metal implants and thus contribute to the movement of the joint. It would appear that removal of the implants, when infected and loose, enables control of the infection. The incidence of infection is thought to have been in part due to the prolonged surgical procedure permitting greater opportunity for contamination. 4) Inadequate articular cartilage removal. the presence of unaltered articular cartilage between the two subchondral bone ends prevent primary bone union from occurring. Because of the impairment in blood supply a cartilaginous callus preceded an osseous callus in these areas.

In two two-year old horses (3 and 10) problems were encountered due to inadequate bone strength. A compressive force could not be achieved with two cancellous screws. In horse #10 no cancellous screws were placed. This horse progressed to achieve a cartilaginous ankylosis. However, prolonged periods of casting were necessary. The small size of this horse and the great osteoblastic activity in this age of horse allowed this ankylosis to occur. In horse #3 the lateral screw pulled through the cortex of the middle phalanx. Thus poor compression was achieved. It is interesting to note that in horse #10 no dorsiflexion of the joint occurred following surgery even though compression screws were not present.

In horses 4 and 12 the process of removing the articular cartilage weakened the extensor process. In horse #4 this defect subsequently filled in with new bone. In addition to the weakened extensor process in horse #12, the screws passed through the palmar half of the joint. This produced a tension band effect. Thus when weight was borne on the limb, the dorsal surface of the joint was under an additional compressive force. During the postoperative phase the extensor process fractured and stimulated an additional external callus which eventually reunited the extensor process and the distal phalanx.

All twelve horses showed some degree of lameness at the time of euthanasia. However, there was a definite decrease in the severity of this lameness as time passed. Histologically it would appear that navicular disease was created in many of these horses (horses #3, 4, 7, 8, 9, and 11). In some cases (horses #3 and 11) the navicular disease was severe enough to induce adhesions between the deep digital flexor tendon and the navicular bone. In horse #4 a chronic tendonitis of the deep digital flexor was produced. Undoubtedly the navicular disease contributed to the lameness. A better understanding is necessary of the changes that occur in the bio-

mechanics of the navicular bone when the distal interphalangeal joint is ankylosed. Obviously due to the range of motion of the distal interphalangeal joint, ankylosis places additional stress on other structures. This was demonstrated in horse #12. The entire shape of the diaphysis of the first phalanx appeared to be changing. A periosteal new bone production was present on the first phalanx at the attachment of the collateral ligaments of the proximal interphalangeal joint. A periosteal reaction at the attachment of the middle distal sesamoidean ligament, which was present prior to surgery, became more extensive. Considering that all cases except horse #1 developed an external callus, it is possible that a degree of lameness could have been produced by the resulting pressure on the inner sensitive structures of the hoof.

The distal interphalangeal joint has many stresses applied to it in a weight-bearing state. A cast does not completely restrict these stresses; it only minimizes them. A small degree of movement seems inherent with the technique utilized in this project. All cases demonstrated progression towards ankylosis. Those observed for longer postsurgical periods reached at least a cartilaginous callus that was undergoing ossification. Thus the degree of motion that existed did not seem sufficient to create a non-union.

Suggested changes in the surgical procedure to enhance osseous union are: 1) Complete removal of articular cartilage. 2) Decreased surgery time to reduce chances of contamination during surgery. 3) Incorporation of the distal limb in a cast for at least eight weeks. These changes should allow a more rapid ankylosis of the distal interphalangeal joint.

SUMMARY

A technique for surgical arthrodesis of the distal interphalangeal joint is described. Radiographical, clinical, gross pathological, and histopathological results, from twelve horses are discussed. Although it is possible to

arthrodese the distal interphalangeal joint the results suggest that the technique is not satisfactory as a treatment for osteoarthritis of this joint because of the development of a degree of navicular disease in a high percentage of the cases.

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TABLE 1

CLINICAL AND RADIOGRAPHICAL FINDINGS

Days Postsurgery	1 27	2 113	3 122	4 123	5 185	6 190	7 195	8 197	9 202	10 233	11 238	12 261
Lysis:												
periphery of bone graft.	*											
bone graft.												
articular surface of distal and middle phalanges.				*								
compression screw site.		*	*								*	
site of bone screw removal.			*					*				
External Callus:												
dorsal surface.		*	*	*	*	*	*	*	*	*	*	*
palmar surface.		*	*	*		*	*	*	*	*	*	*
involving navicular bone.		*	*	*	*	*	*	*	*	*	*	*
Navicular Bone:												
roughening of flexor border.			*				*		*		*	*
anatomical displacement.			*					*	*			
Effect of Movement:												
screw displacement.			*						*			*
sclerosis of apposing surfaces of middle and distal phalanges.						*	*	*				
entire joint space visible.	*	*	*	*		*	*	*	*			
dorsiflexion of joint postsurgery.			*	*			*		*			*
Calcification of Extensor Tendon:								*	*			
Pedal Osteitis:	*							*	*		*	*
Assessment:												
previous lysis around screw becoming radiodense.				*								*
osseous union of navicular bone to middle and distal phalanges.					*	*	*			*		
periosteal reaction less than previously observed.					*		*	*	*	*	*	
narrowing of joint space.				*	*			*				
osseous union of middle and distal phalanges.					*				*	*	*	*
Degree of Lameness:												
slight						*	*		*	*	*	*
moderate		*	*									
severe	*		*	*								

TABLE 2

HISTOPATHOLOGICAL FINDINGS	HORSE NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
Days postsurgery	27	113	122	123	185	190	195	197	202	233	238	261
Articular Cartilage: degenerative portions present.	*		*		*	*	*	*				
none present.		*		*					*	*	*	*
Bone Graft: inactive.	*					*		*		*		*
osteoblastic activity on periphery.				*	*				*		*	
surrounded by fibrous tissue.				*		*	*					
sequestration.		*	*									
Joint Space: filled with fibrous tissue.		*	*									
polymorphonuclear cells present.			*									
cartilaginous callus.					*		*	*		*	*	*
osseous callus.					*		*	*				
Navicular Bone: degeneration of flexor surface.			*	*			*	*	*		*	
adhesion to flexor tendon.			*								*	
Tendonitis of Deep Digital Flexor:				*								
Marked Osteoblastic Activity in Bone Adjacent to Joint:			*									

Fig. 1. Positioning for lateral radiograph.

Fig. 2. Positioning for anterior-posterior radiograph.

Fig. 3. Lateral view of hoof demonstrating center of X-ray beam and
location of lead shot markers.

Fig. 4. Anterior-posterior view of hoof demonstrating center of X-ray
beam and location of lead shot markers.

Fig. 1
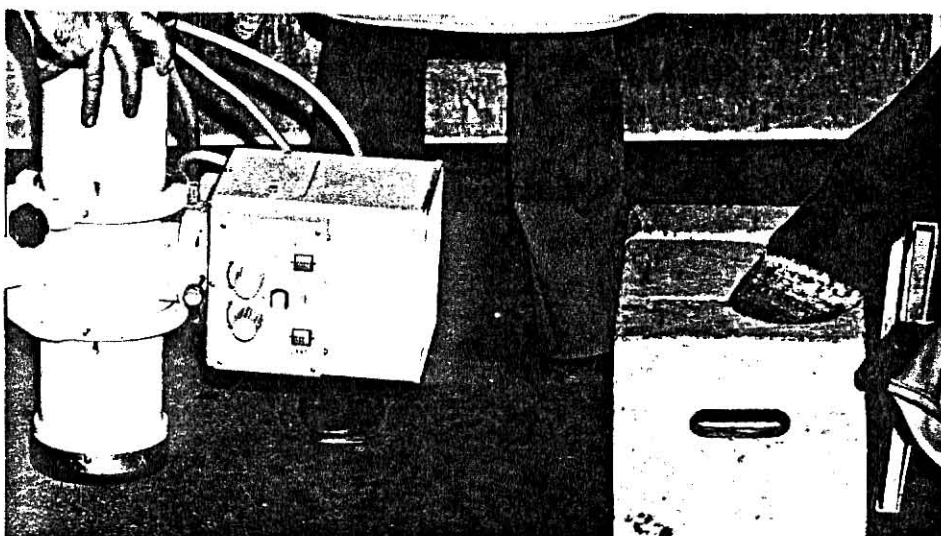
Fig. 2

Fig. 3
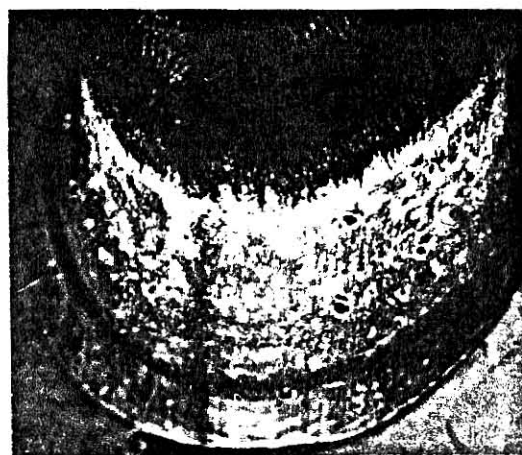
Fig. 4

Fig. 5.   A line was drawn on the lateral radiograph where the first screw
          will lie. This line was drawn from a point on the middle phalanx
          situated half way between the dorsal and palmar surfaces and at
          the junction of the proximal and middle thirds. From this point
          the line was drawn to parallel the dorsal surface of the distal
          phalanx and to be 1.2 centimeters palmar to this surface.

Fig. 6.   A line was drawn on the lateral radiograph where the second
          screw will lie. This line was drawn from a point on the middle
          phalanx situated half way between the dorsal and palmar surfaces
          and at the junction of the proximal and middle thirds. From this
          point the line was drawn so as to arrive on the solar surface of
          the distal phalanx just dorsal to the most dorsal portion of the
          semilunar line.

Fig. 7.   Marks were placed on the hoof in the same location as where the
          lines passed over the distal margin of the hoof on the radio-
          graphs.
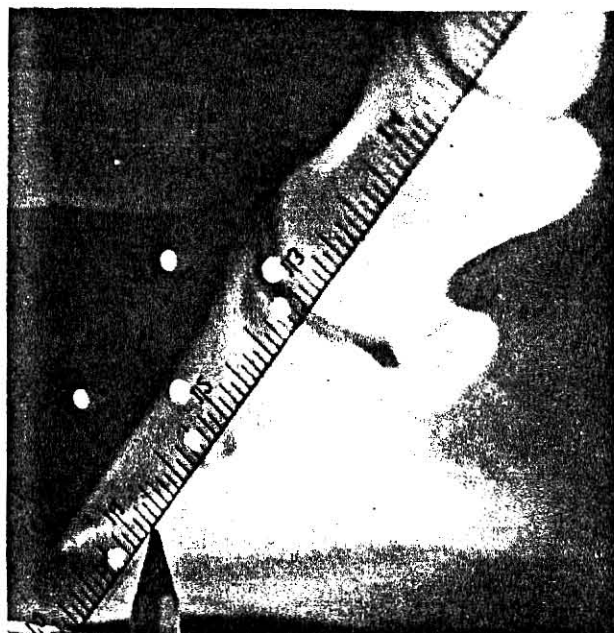
Fig. 5
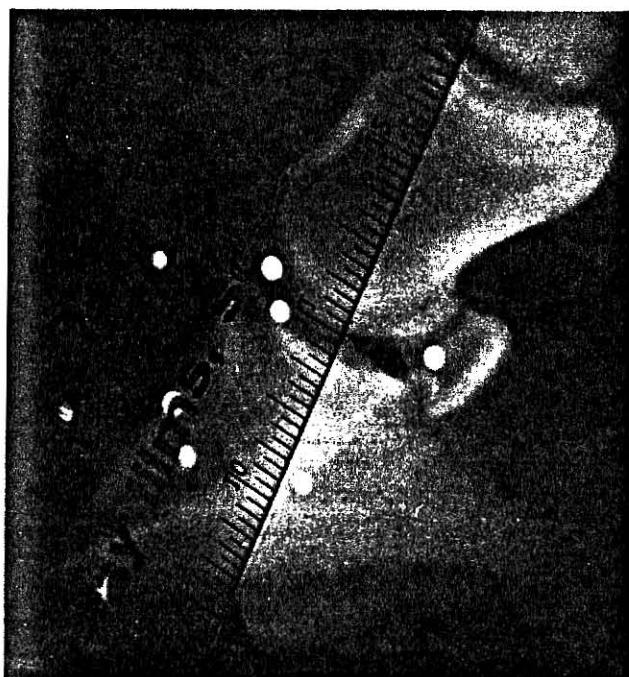
Fig. 6

Fig. 7

Fig. 8. Two lines were drawn with a straight edge on the anterior-posterior radiograph from points on both the lateral and medial surfaces in the depression present at the junction between the proximal and middle thirds of the middle phalanx, to the middle of the solar border of the distal phalanx on the medial and lateral sides respectively.

Fig. 9. Holes were drilled in the hoof wall to act as guide holes for the C-clamp.
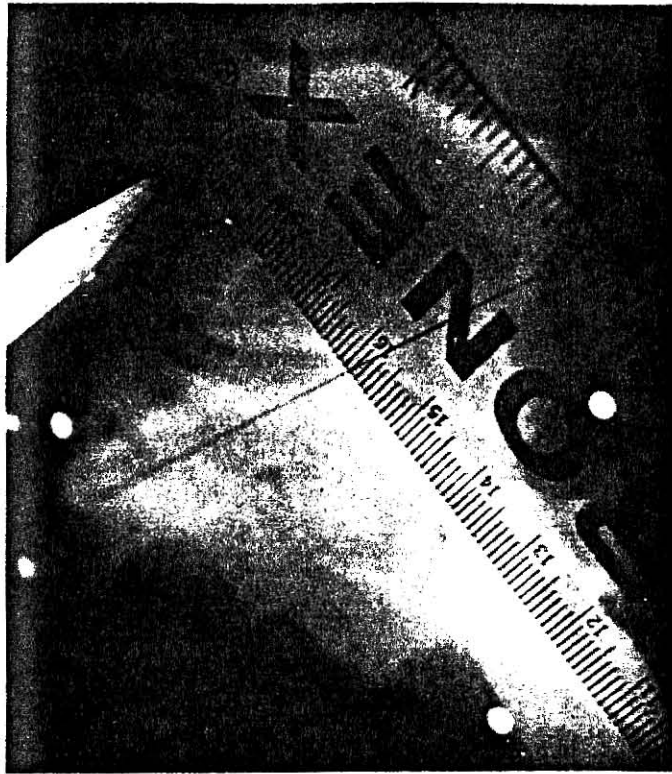
Fig. 8

Fig. 9

Fig. 10. A sterile Esmarch bandage was applied from the hoof to the carpus.

Fig. 11. A nitrogen powered Stryker oscillating saw with a 1/4 inch blade was used to remove a section of hoof wall.
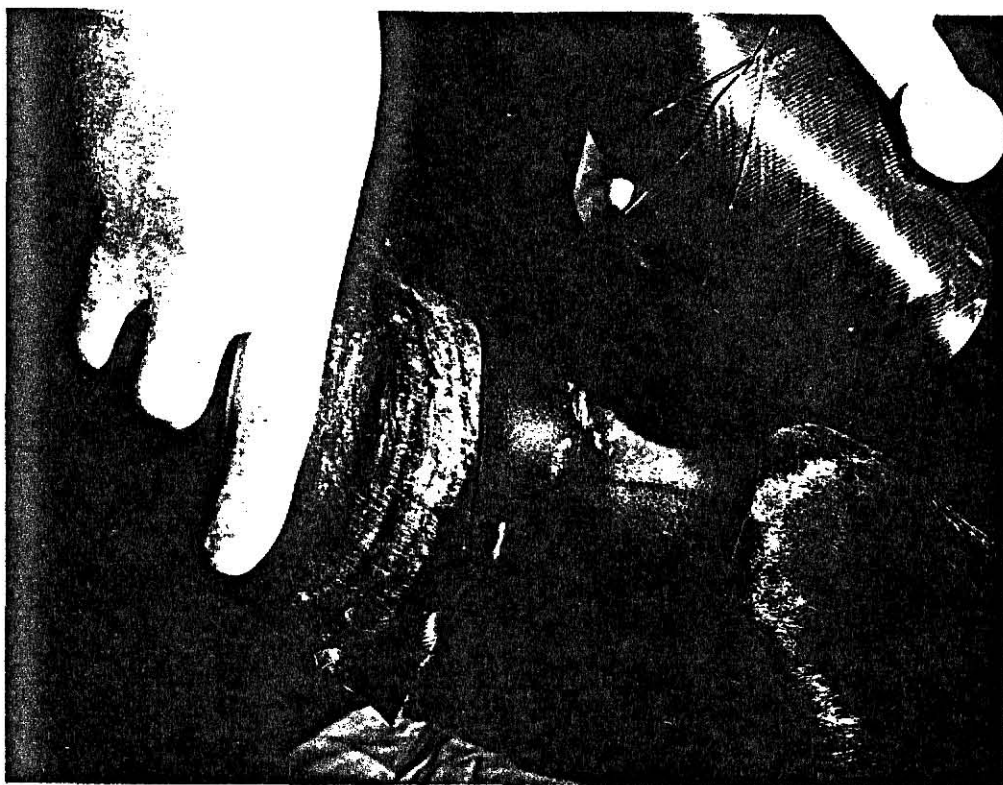
Fig. 10
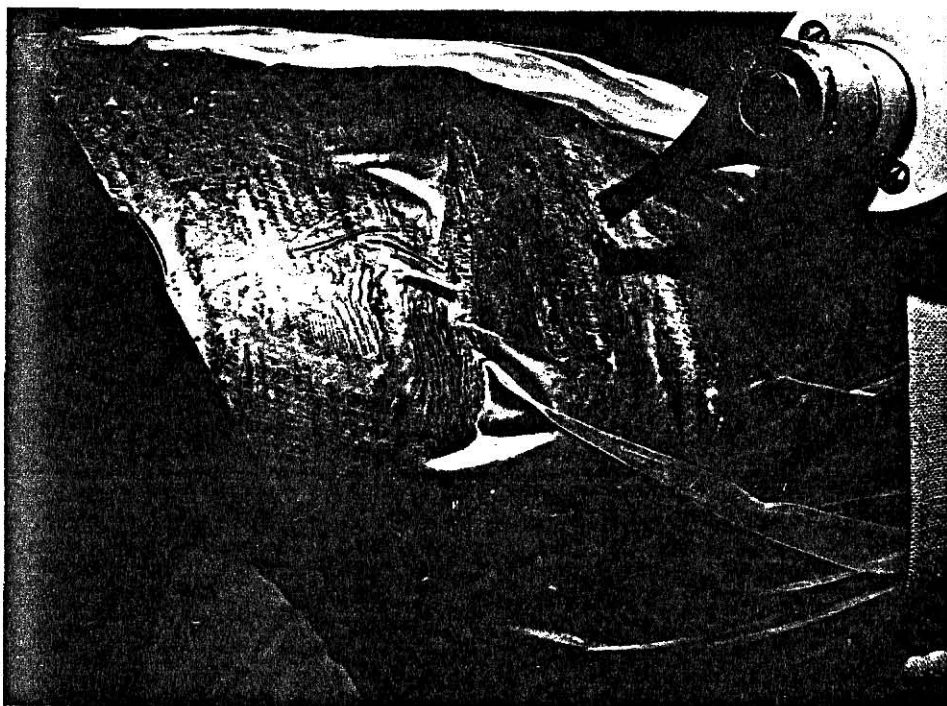
Fig. 11

Fig. 12. A nitrogen powered Stryker drill with a 4.5 millimeter drill
          bit was used to loosen as much articular cartilage as possible.

Fig. 13. A periosteal elevator was used to lift the periosteum from the
          cortex of the pelvis.

Fig. 14. A 1/4 inch bone chisel was used to remove a section of the
          cortex of the pelvis.
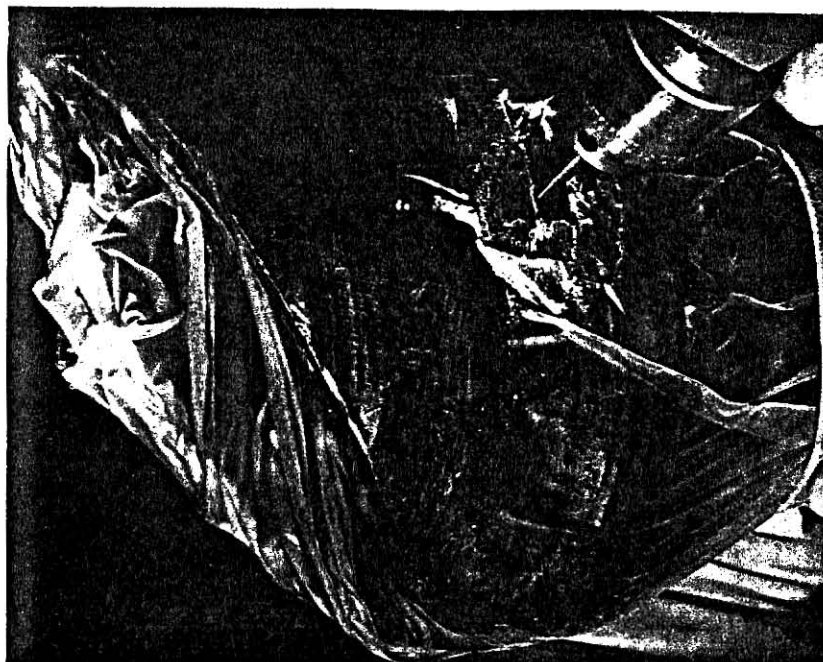
Fig. 12
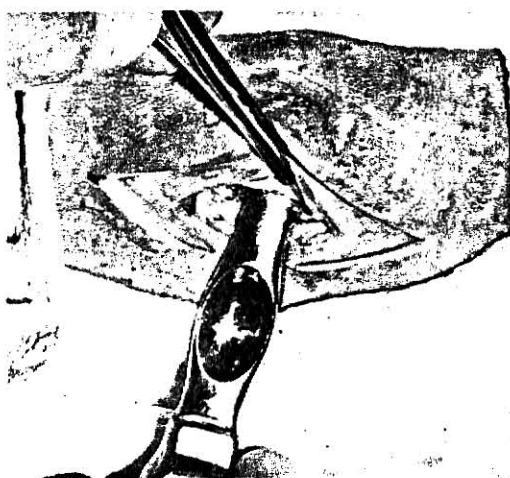
Fig. 13

Fig. 14

Fig. 15. A large spooned currette was used to harvest the cancellous bone chips.

Fig. 16. The cancellous bone graft was stored on saline-soaked guaze sponges in a bowl.
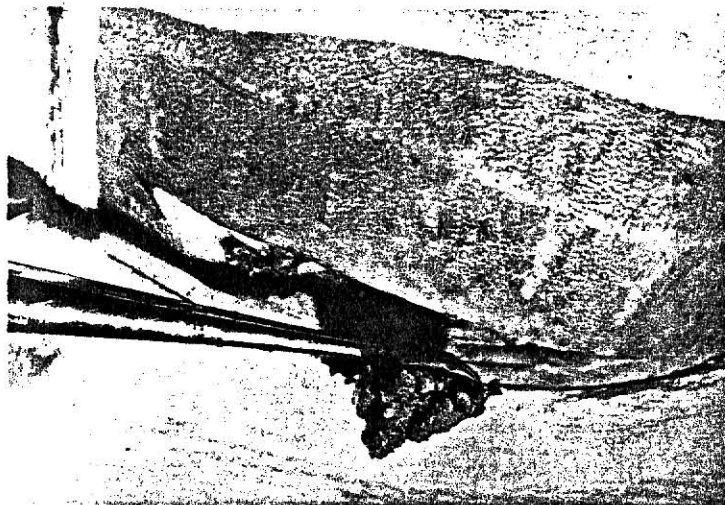
Fig. 15
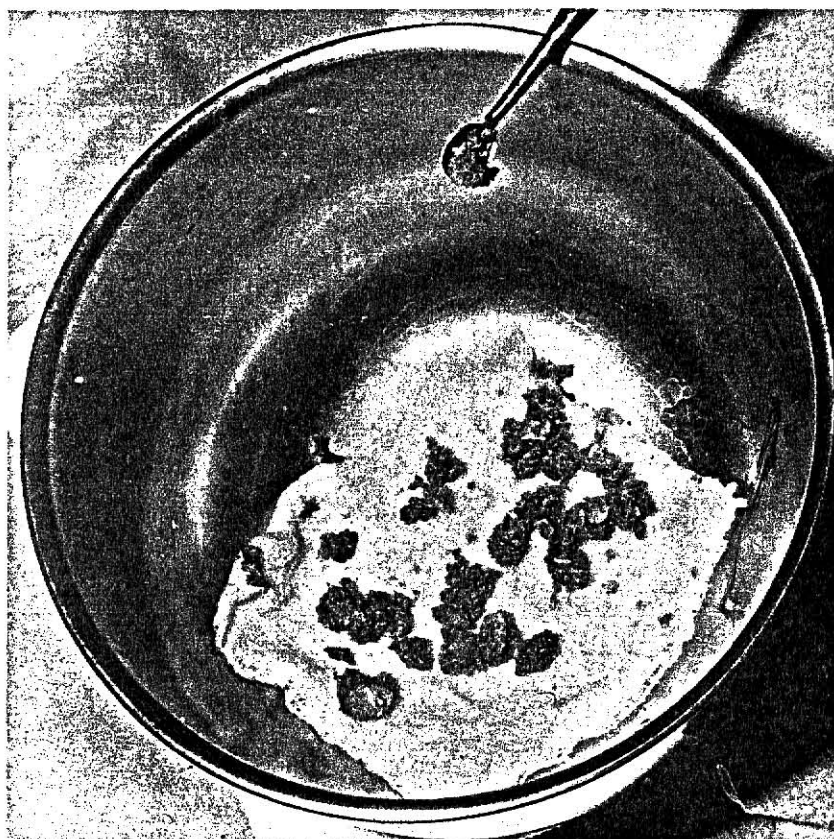
Fig. 16

Fig. 17.   The oversew bandage over the incision on the tuber coxae.

Fig. 18.   Packing the cancellous bone graft in the distal interpha-
            langeal joint.
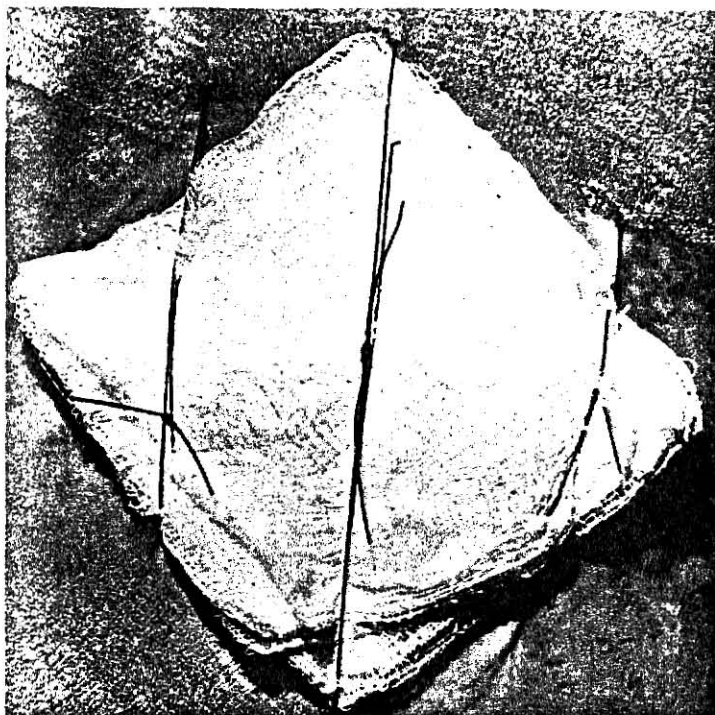
Fig. 17
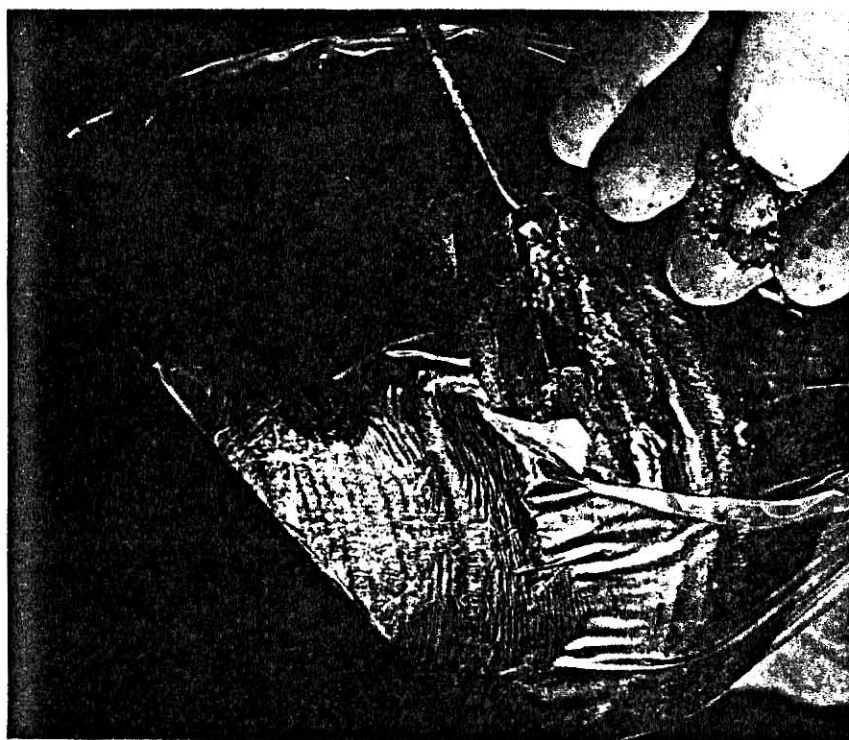
Fig. 18

Fig. 19. Palpation of the proximal palmar surface of the middle phalanx.

Fig. 20. Measuring location of stab incision from proximal palmar surface
of the middle phalanx.
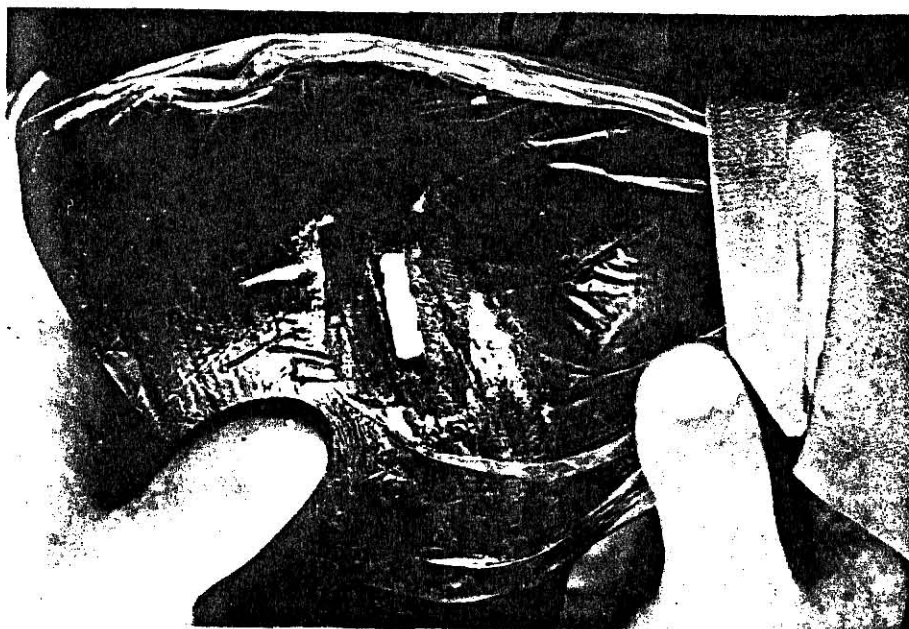
Fig. 19

Fig. 20

Fig. 21.   Placing the C-clamp with the distal interphalangeal joint held
          in extension.

Fig. 22,   Measuring the portion of the 4.5 millimeter drill bit pro-
          truding from the C-clamp.
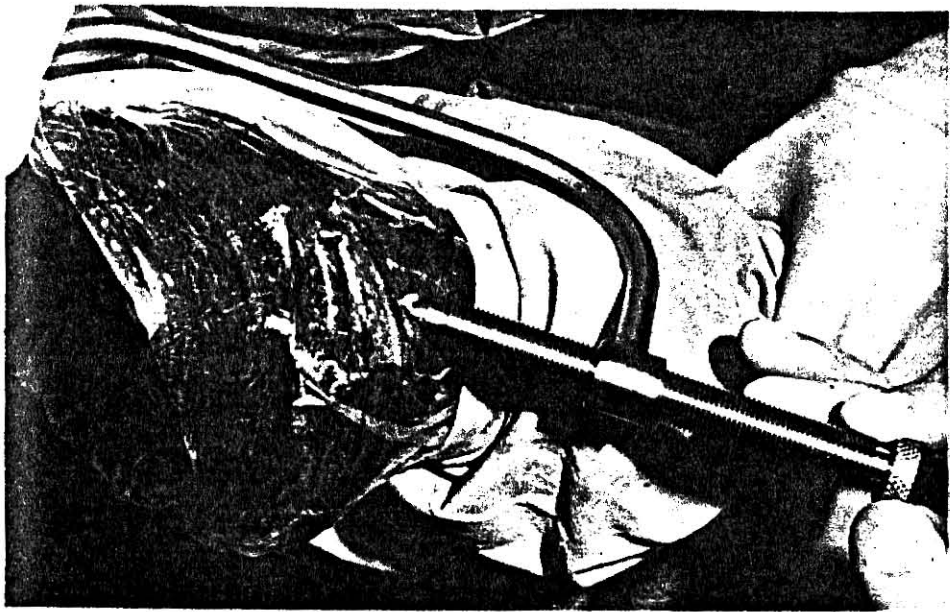
Fig. 21
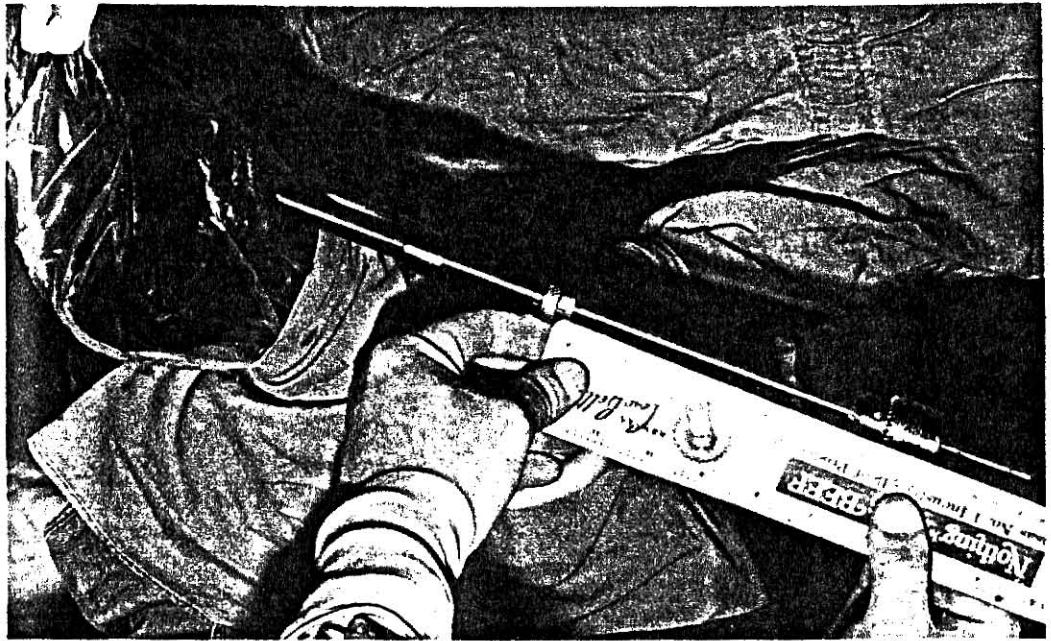
Fig. 22

Fig. 23. A cancellous tap was used to tap the threads in the hole.

Fig. 24. Measuring the depth of the hole.
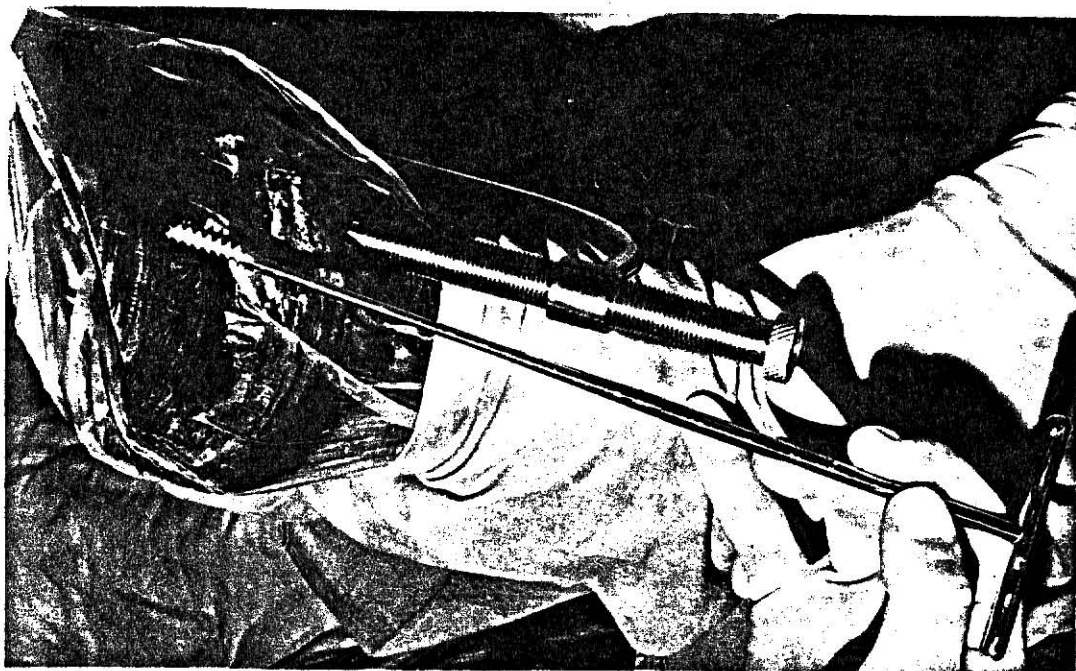
Fig. 23

Fig. 24

Fig. 25. Placing the cancellous screw of the appropriate length.

Fig. 26. Demonstration of the closure of the skin incision, the repair of the hoof defect, and the use of a metal bar for supporting the cast.
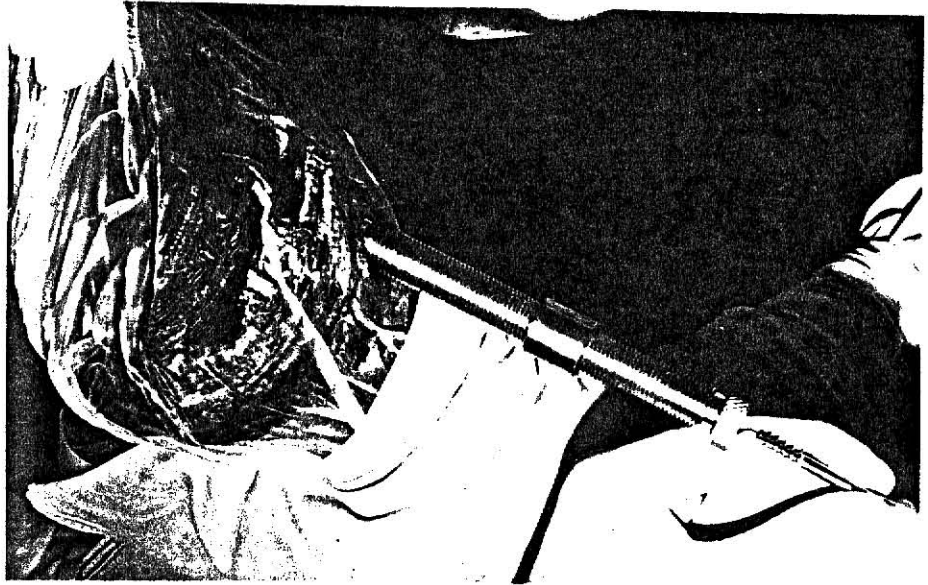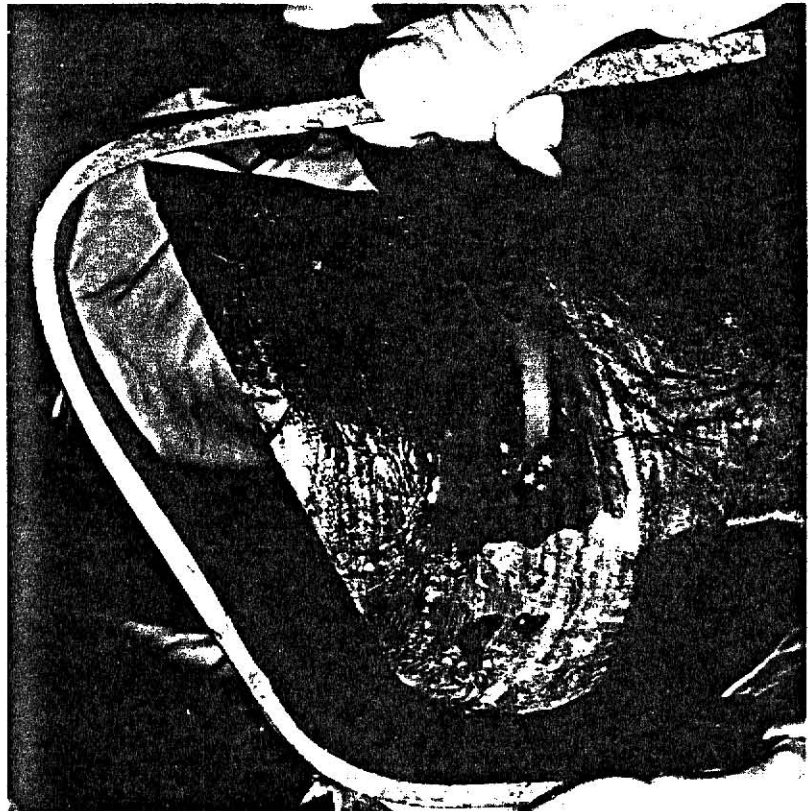
Fig. 25

Fig. 26

Figs. 27 and 28.   Lateral and anterior-posterior radiographic views of
                     Horse #4. A periosteal reaction was present on the
                     dorsal surface of the middle phalanx and the extensor
                     process of the distal phalanx. There was new bone
                     growth on all surfaces of the navicular bone except
                     the flexor surface. Although the joint space and the
                     area around the screw shafts had previously appeared
                     lytic, these areas were becoming more radiodense.

Figs. 29 and 30.   Anterior-posterior and lateral radiographic views of
                     Horse #6. The joint space was clearly visible.
                     Periosteal reaction was evident on the dorsal surface
                     of the middle phalanx and the extensor process of the
                     distal phalanx. A bony union was present between the
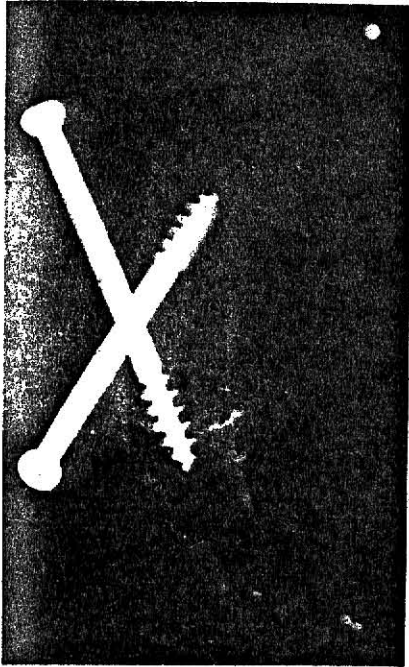   navicular bone and the distal phalanx.

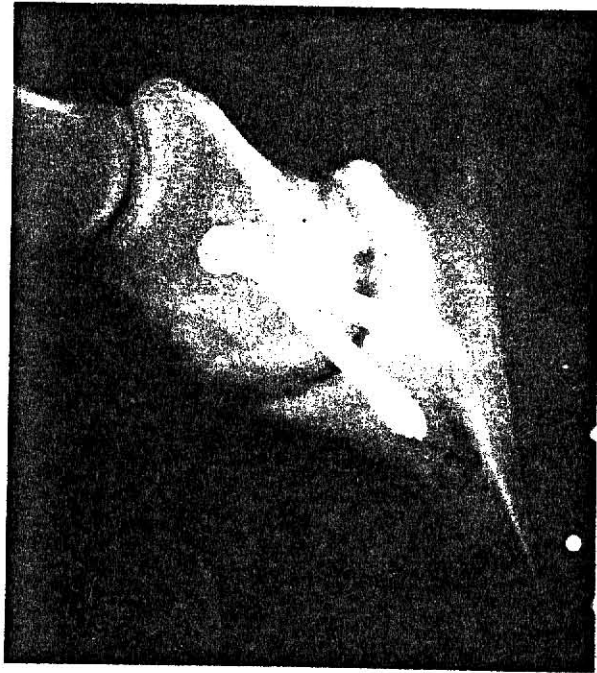Fig. 28
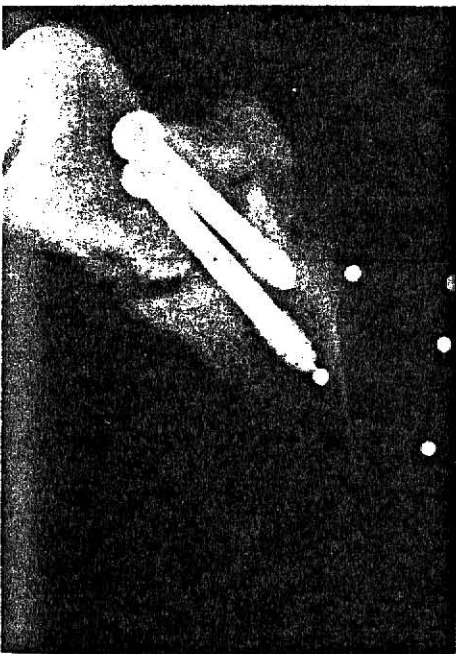

Fig. 30

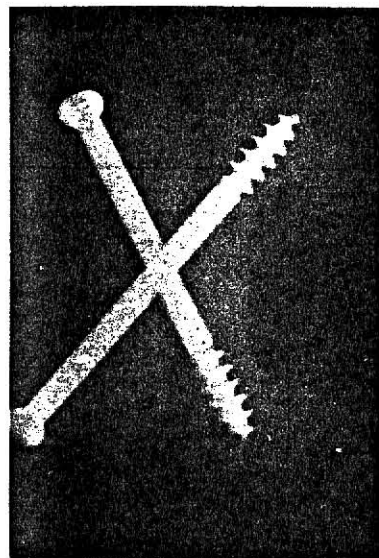Fig. 27

Fig. 29

Figs. 31 and 32.   Lateral and anterior-posterior radiographic views of
                   Horse #7. A marked periosteal new bone growth was
                   present on the dorsal middle phalanx and the extensor
                   process of the distal phalanx. Periosteal proliferation
                   on the palmar aspect united the navicular bone with the
                   middle and distal phalanges. The entire joint space
                   was still evident. The apposing surfaces of the middle
                   and distal phalanges were sclerotic.

Figs. 33 and 34.   Anterior-posterior and lateral radiographic views of
                   Horse #8. Infection had been a problem earlier in the
                   postoperative phase and both screws were removed.
                   Zones of lysis were present where both screws were
                   present. The entire joint space was visible. An
                   external callus was present on the dorsal and palmar
                   surfaces of the joint. Pedal osteitis was very pro-
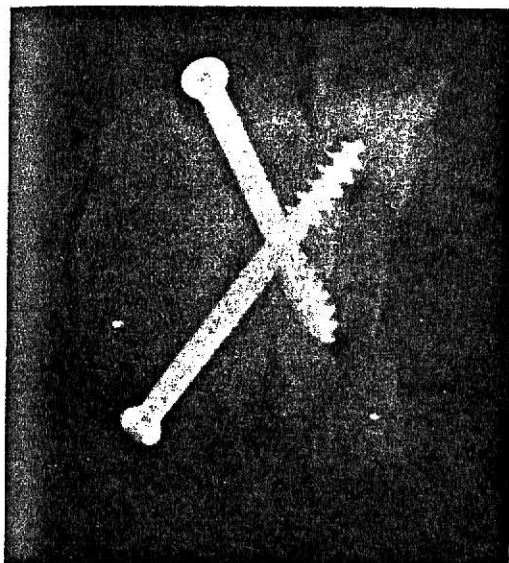   nounced.

Fig. 32

Fig. 34

Fig. 31

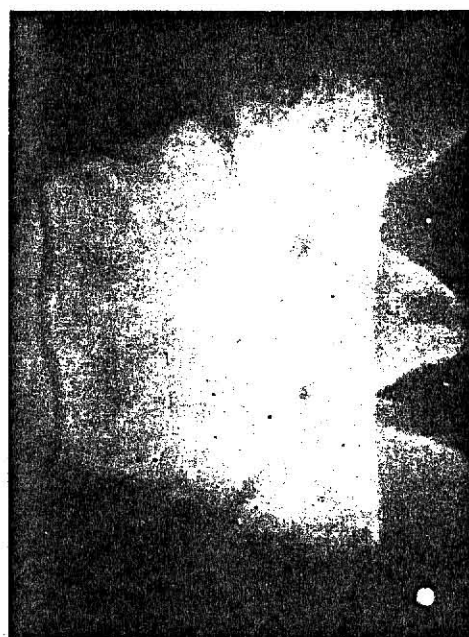Fig. 33

Figs. 35 and 36.   Lateral and anterior-posterior radiographic views of
                    Horse #10. The middle and distal phalanges were too
                    soft to provide compression and thus the screws were
                    taken out at the time of surgery. The joint space was
                    still visible but was filling in with radiodense
                    material. The external callus incorporated the navicular
                    bone. The periosteal reaction in the dorsal callus was
                    decreasing in activity and the pedal osteitis was minimal.

Figs. 37 and 38.   Lateral and anterior-posterior radiographic views of
                    Horse #11. There was a homogeneous bone density from
                    the middle to the distal phalanx. The navicular bone
                    was incorporated into the bony callus and had changed
                    shape completely. A slight degree of lysis was pre-
                    sent around both screw threads. A bony spur was
                    present at the joint capsule attachment on the proxi-
                    mal portion of the middle phalanx.

Fig. 36

Fig. 38

Fig. 35
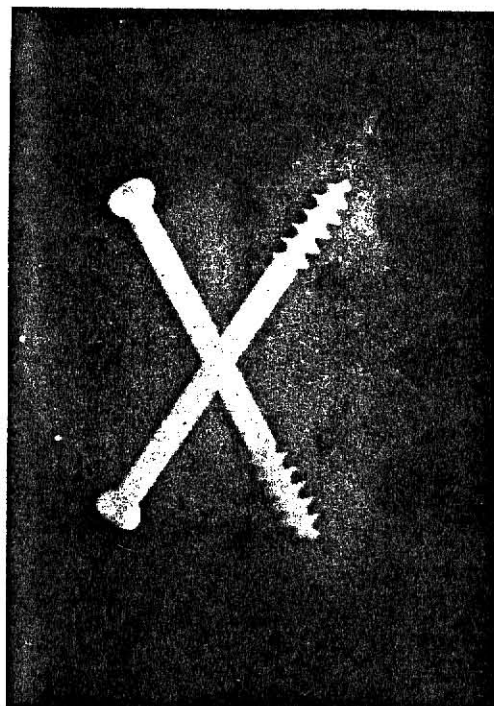

Fig. 37

Figs. 39 and 40.   Lateral and anterior-posterior radiographic views of
                   Horse #12. There appears to be a complete bony ankylosis.
                   The periosteal reaction was decreasing in activity.
                   Lysis which was present around both screws previously
                   was now filling in with a radiodense material. Pedal
                   osteitis was present at the site of the previous extensor
                   process fracture. An old but active periosteal pro-
                   liferation was present on the proximal phalanx at the
                   attachment of the collateral ligaments of the proximal
                   interphalangeal joint and at the attachment of the
                   middle distal sesamoidean ligament. The latter was
                   present to a lesser degree prior to surgery. The dia-
                   physis of the proximal phalanx was both sclerotic and
                   lytic and the entire shape of this portion of the
                   proximal phalanx appeared to be changing.

Fig. 41.   Appearance of middle and distal phalanges with screws
                   in position.

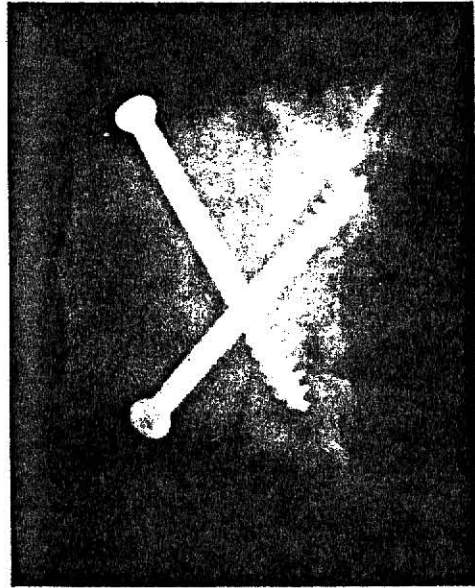Fig. 39
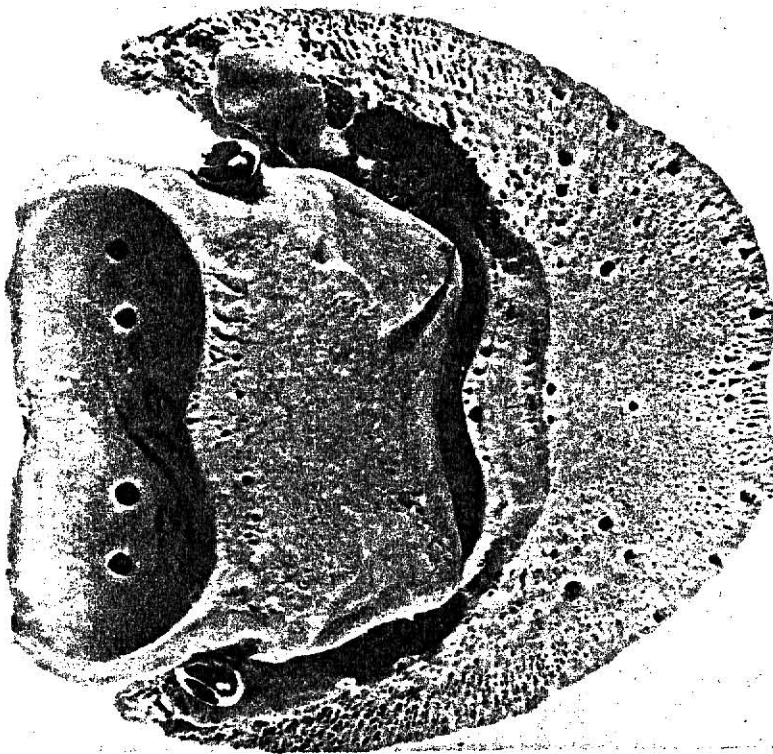

Fig. 40

Fig. 41

Figs. 42 and 43.   Appearance of middle and distal phalanges with screws
                   in position. This was performed on a cadaver limb and
                   no attempt was made to remove articular cartilage, thus
                   the appearance of poor compression.
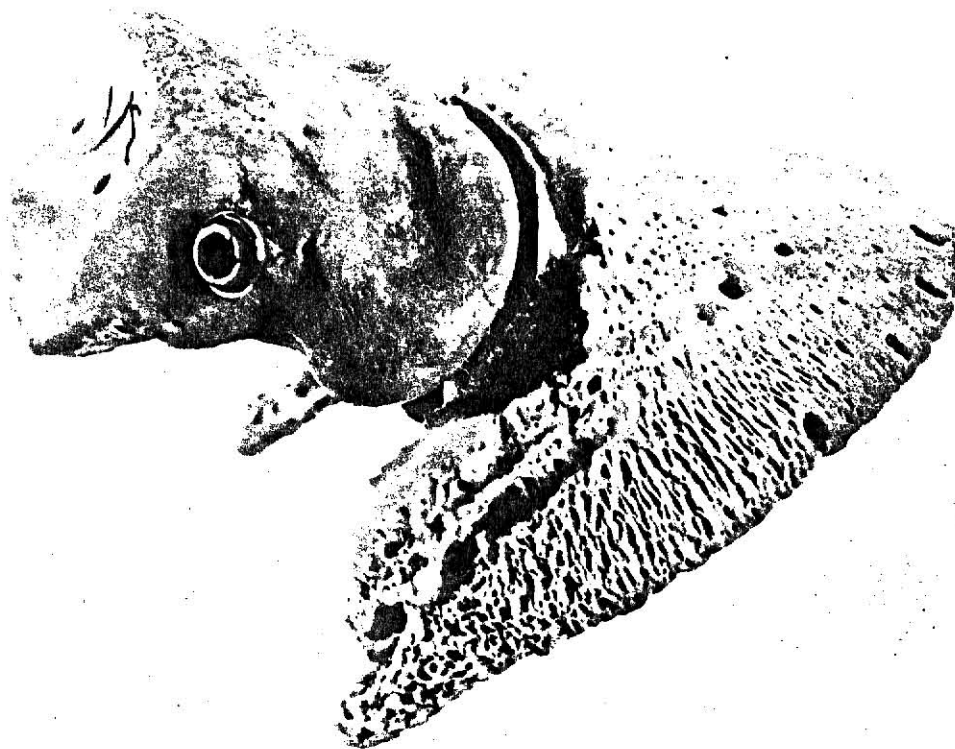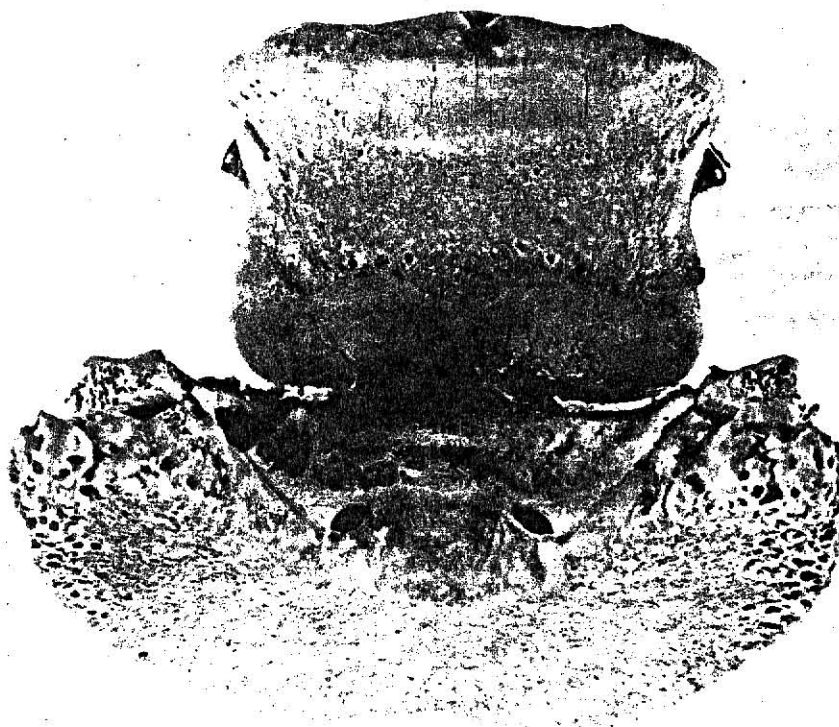
Fig. 42

Fig. 43

Fig. 44.   The screw canal in the location of the shaft of the cancellous
           screw was filled with vascularized connective tissue.
           H & E stain, 60X.

Fig. 45.   The bone marrow next to the articular surfaces was replaced
           with a fine network of fibrous tissue and adipose tissue.
           H & E stain, 200X.

Fig. 46.   Some articular cartilage was present but was degenerating.
           The bone graft showed no osteoblastic or osteoclastic activity.
           H & E stain, 100X.

Fig. 47.   The cancellous bone graft had sequestered and was surrounded
           with foreign body giant cells, macrophages, and a sprinkling
           of polymorphonuclear cells.
           H & E stain, 100X.

Fig. 44

Fig. 45

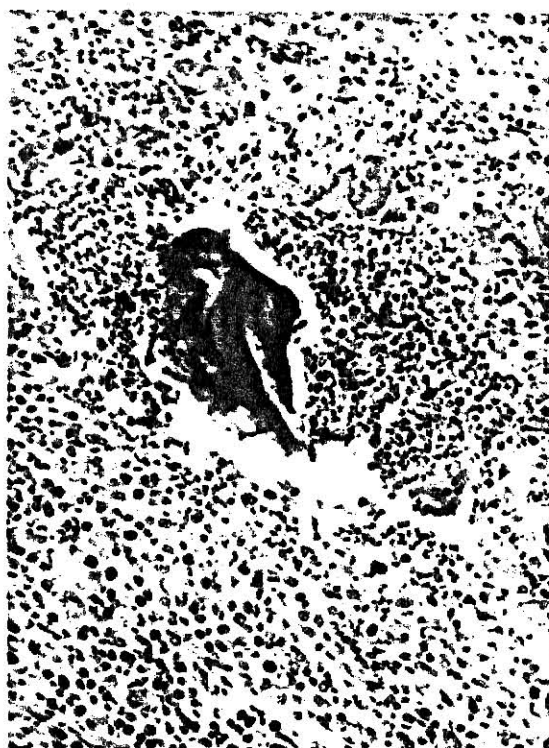
Fig. 46

Fig. 47

Fig. 48.   A sequestrum of cancellous bone graft surrounded by a foreign
           body reaction with many active giant cells.
           H & E stain, 100X.

Fig. 49.   Osteoblastic and osteoclastic activity involving the cancellous
           bone graft.
           H & E stain, 100X.

Fig. 50.   Fibrous tissue surrounding cancellous bone graft.
           H & E stain, 100X.

Fig. 51.   Chronic tendonitis of the deep digital flexor as it passed
           over the navicular bone.
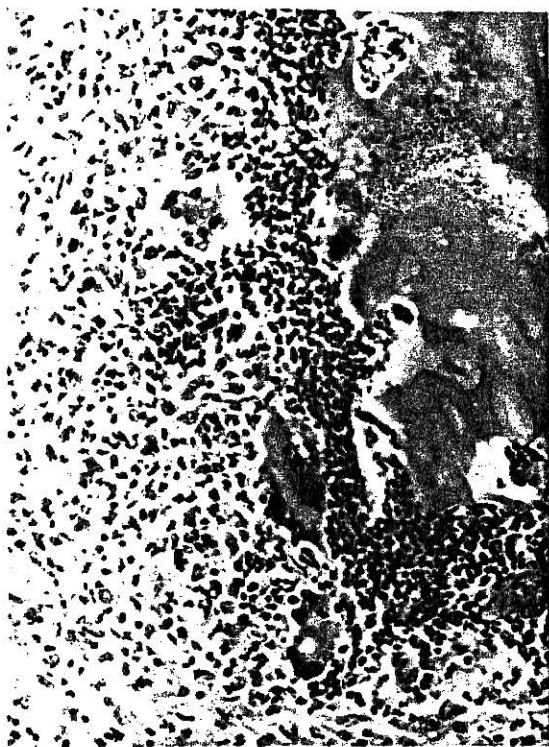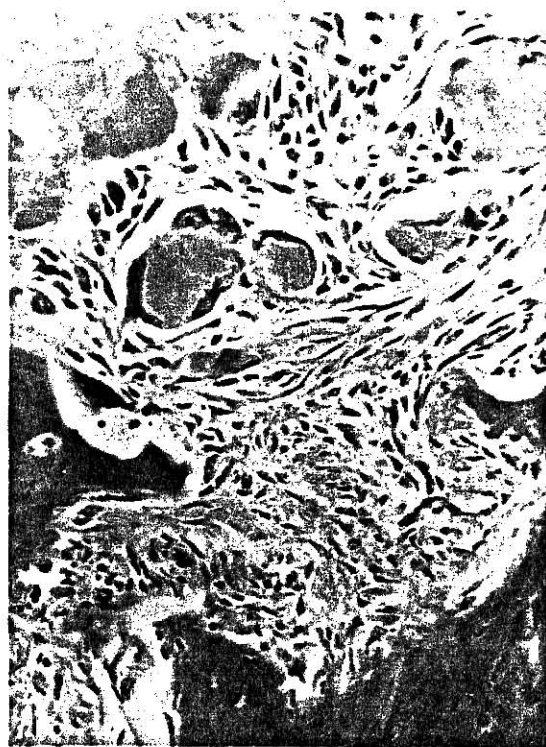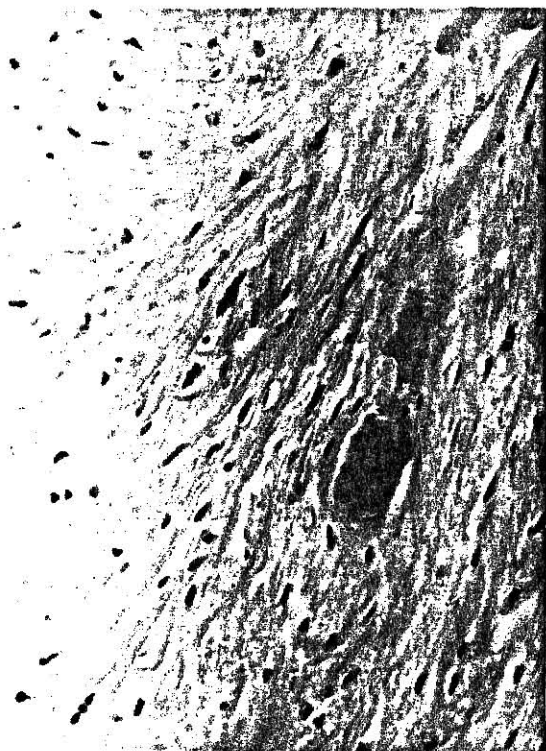   H & E stain, 100X.

Fig. 48

Fig. 49

Fig. 50
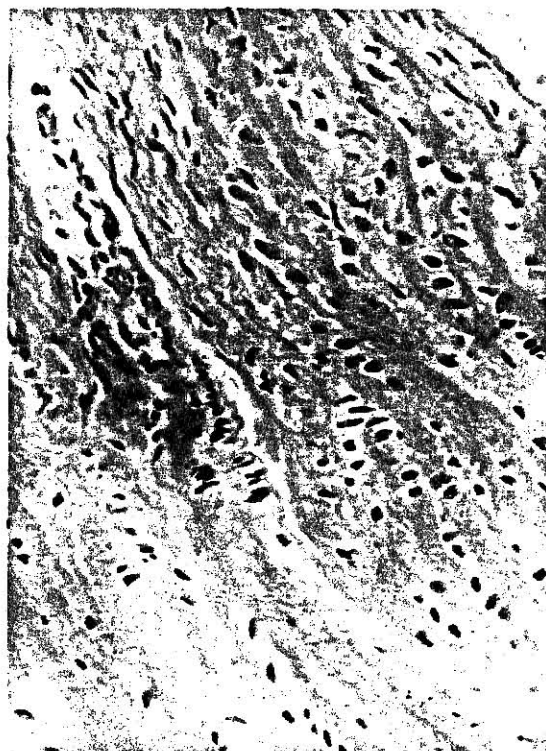
Fig. 51

Fig. 52.   Cartilaginous callus with cancellous bone graft surrounded by fibrous tissue.
H & E stain, 100X.

Fig. 53.   A narrow layer of cartilage callus separated the surfaces of the middle and distal phalanges.
H & E stain, 60X.

Fig. 54.   The cancellous bone graft was intermixed with the fibrocart-ilaginous callus in the joint space.
H & E stain, 100X.

Fig. 55.   Adhesions of the deep digital flexor tendon to the navicular bone.
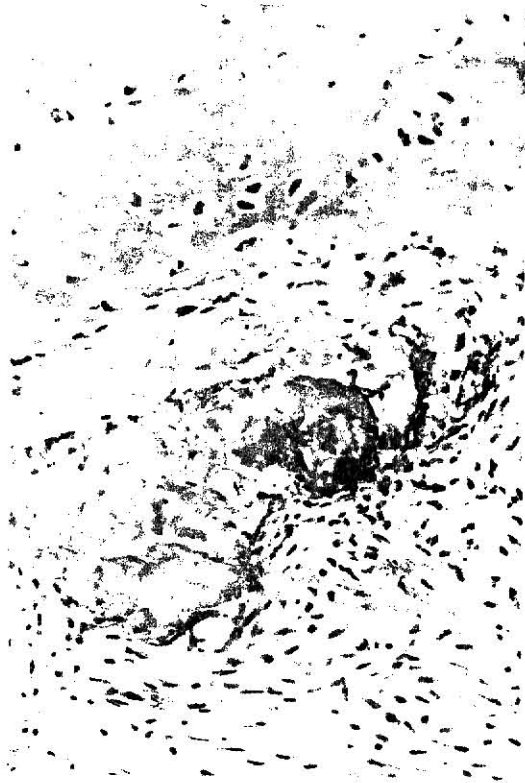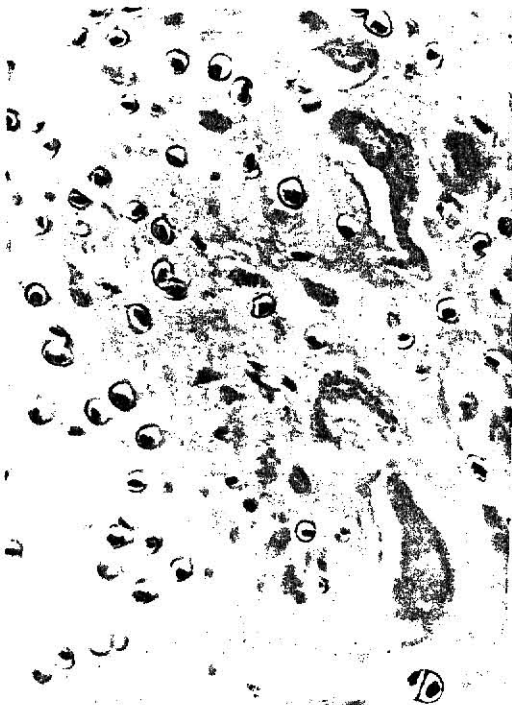H & E stain, 200X.

Fig. 52

Fig. 53

Fig. 54

Fig. 55

Paper 2

A LARGE C-CLAMP DRILL GUIDE FOR USE IN

LARGE ANIMAL ORTHOPEDICS

INTRODUCTION

An ASIF[1] C-clamp is an instrument designed to aid in the proper placement of compression screws. This is achieved by placing the guide end of the C-clamp where the screw should be directed and by placing the clamp end of the C-clamp in the location where the head of the screw should lie. When the drill bit is guided by the guide portion of the C-clamp, the resulting screw hole will be exactly in its predetermined location. At the present time an ASIF C-clamp drill guide of sufficient size to be used for equine orthopedic procedures is not available. For many orthopedic procedures requiring the precise placement of a compression screw, like screw fixation of distal phalangeal fractures, such an instrument would be very useful and at times essential.

MATERIALS AND METHODS

Stainless steel was utilized in the construction of the C-clamp to provide necessary strength and corrosion-resistant characteristics. The C-clamp was designed to accomodate the entire procedure of screw placement with one setting and for easy dismantling for cleaning purposes. The C portion of the clamp (a in Figure 1) was constructed from 3/8 inch stainless steel rod. The inside dimensions of the C were 3 5/8 by 7 1/2 inches. On the guide end of the C a point protruded inwards 1/2 inch (b in Figure 1). On the other end of the C was welded an 11/16 inch long piece of 3/4 inch stainless steel rod (c in Figure 1). This piece of rod was drilled out and tapped to accept the

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[1]ASIF – Association for the Study of Internal Fixation.

threads on the clamp portion of the C-clamp (d in Figure 1). The clamp portion of the C-clamp was 5 1/8 inches in length and was constructed from 3/4 inch stainless steel rod. On all but 1/4 inch of the length, the outside diameter was honed down to accept a 9/16 inch national fine thread. The surface of the 1/4 inch long portion of 3/4 inch diameter was roughened to allow easy turning of the threads. The center of this clamp portion was drilled out with a 5/16 inch bit and then enlarged to a diameter of 0.315 inch. This permitted the shaft of an ASIF screwdriver to pass through it (Figure 3). A bushing was placed on the end of the clamp to minimize tissue trauma as the clamp was tightened. The bushing was constructed from 1/2 inch stainless steel rod (e in Figure 1). The portion of the bushing that fit inside the clamp portion of the C-clamp had an outside diameter of 0.357 inch, an inside diameter of 0.315 inch, and a length of 7/8 inch. To accomodate the bushing, this portion of the clamp was drilled out with a 23/64 inch bit to make the inside diameter of the clamp 0.358 inch. The drill guide was made from 1/2 inch stainless steel (f in Figure 1). The drill guide shaft was 5 1/8 inches long and was machined down to an outside diameter of 0.307 inch. This permitted it to fit inside the clamp portion of the C-clamp. A 1/4 inch long collar was present on the end of the shaft to prevent it from sliding into the clamp portion. The surface of this collar was roughened to allow easier handling. The center of the drill guide was drilled out with a 0.180 inch drill bit (#15). This would allow passage of 4.5 millimeter ASIF drill bit (Figure 2). Because of the length of the clamp, the shaft of an ASIF screwdriver had to be lengthened to 9 1/8 inches and a 4.5 millimeter drill bit had to be lengthened to 12 3/8 inches.

DISCUSSION

This C-clamp enabled accurate screw placement in areas where a C-clamp could be used. Because the entire procedure of screw placement can be performed with the C-clamp in position, the C-clamp could be used to aid in the reduction of fracture fragments. The use of the C-clamp thus far has been limited to the placement of cancellous screws. However, with elongation of a cortical tap and use of a 3.2 millimeter guide sleeve, it could be used for the placement of cortical screws as well. The C-clamp drill guide was used experimentally in twelve compression arthrodeses of the distal interphalangeal joint. This instrument allowed precise screw placement.

SUMMARY

A large C-clamp drill guide was developed for use in equine orthopedic procedures. The design and the application of this instrument were discussed.

Fig. 1. Parts of the C-clamp. a-the C portion, b-guide end of the
        C-clamp, c-portion that accepts the threads on the clamp
        portion of the C-clamp, d-clamp portion, e-bushing, and
        f-drill guide.

Fig. 2. Passage of a 4.5 millimeter ASIF drill bit through the drill
        guide.

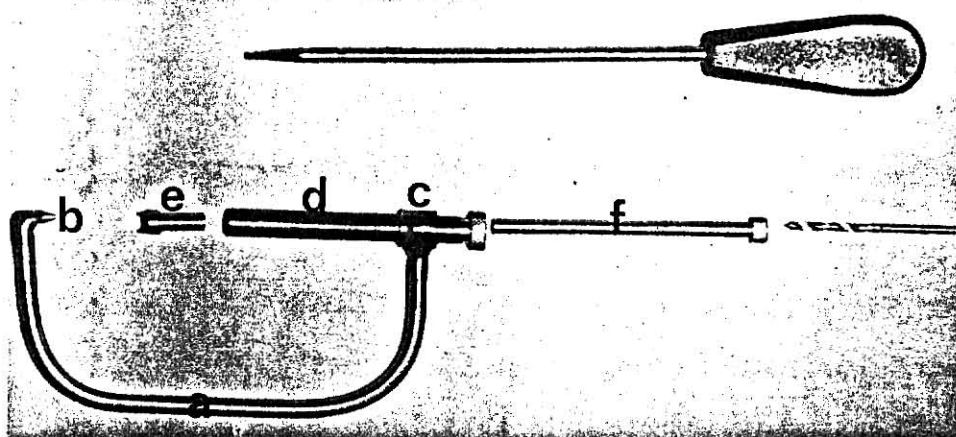Fig. 3. Passage of an ASIF screwdriver through the C-clamp.
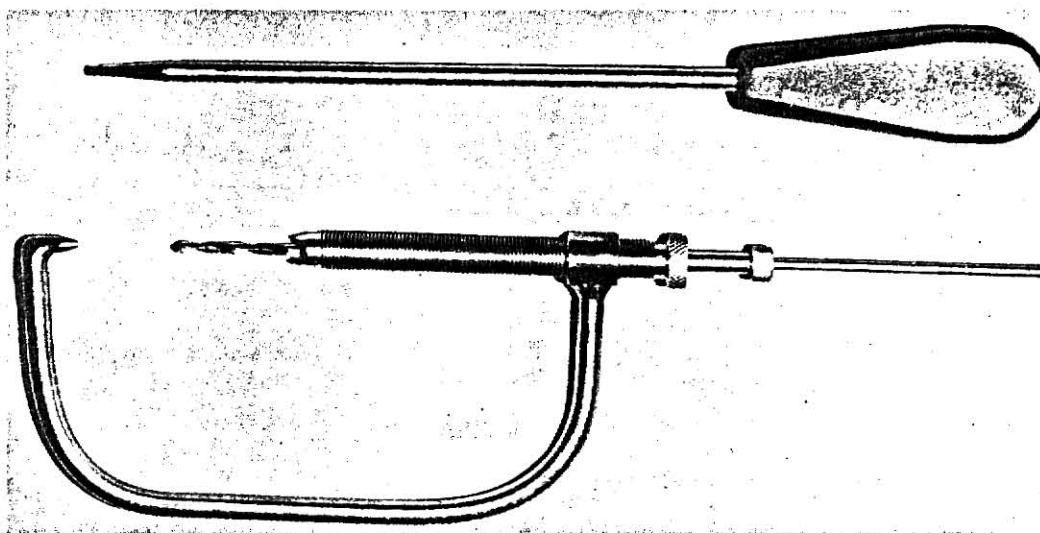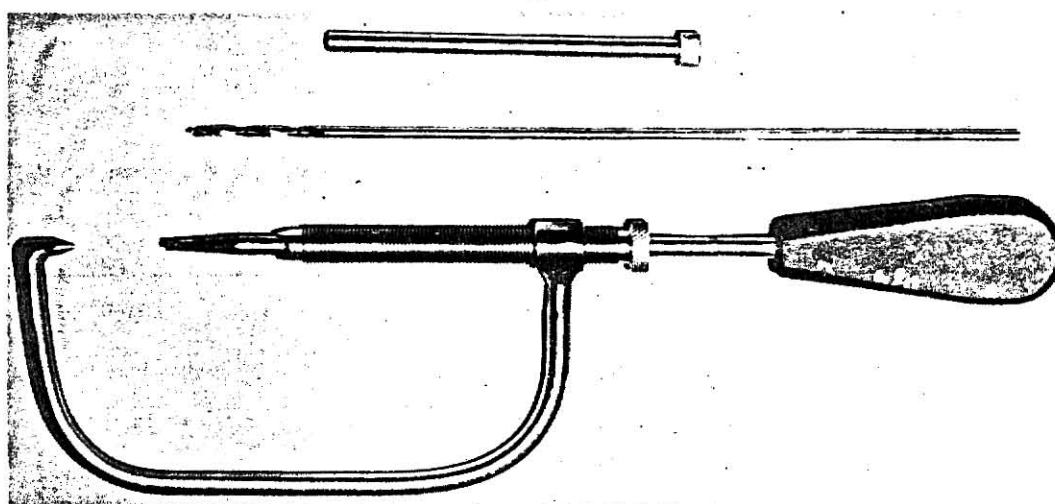
Fig. 1

Fig. 2

Fig. 3

APPENDIX

ADDITIONAL REVIEW OF THE LITERATURE

In human orthopedic surgery, prior to the development of prosthetic joints, arthrodesis was a common surgical treatment for osteoarthritic joints. Bony ankylosis relieved the pain associated with motion and produced a stable joint. Charnley (1953) was one of the first orthopedic surgeons to report good success with joint ankylosis by compression arthrodesis. Based on his experiences he described the theory of compression arthrodesis. Charnley felt that the type of compression achieved was very important. He developed what has later been termed the Charnley Apparatus which possessed a spring in the system. This apparatus was thus able to apply a powerful continuous compression. Charnley explained the results obtained on mechanical and biological factors. The mechanical factors that he described were: 1) Fixation. A rigid union was produced when the articular surfaces were osteotomized and the apposing bone surfaces were compressed with fifty pounds pressure. The spring strength in the system had to exceed the angulatory strain on the joint to prevent a gap from occurring in the apposing surfaces. If a compressor was used with no spring resilience, Charnley felt that the immediate results would appear more rigid but with numerous small strains would eventually become looser. An external splint was used to assist fixation. Charnley recognized that inherent stability would be lacking when the line of contact in the joint was in the same plane as that of the two transfixation pins. This observation is related to what has later been termed the tension band principle (Muller et al., 1970). Charnley did not believe that absolute fixation and absolute apposition over a large area were the essential physical elements in promoting osseous union in arthrodesis by continuous compression. 2) Persistance of intimate contact or apposition. 3) Bone

contact over a large area. Ultimately what Charnley strived for was a high magnitude of compression between the two bone ends providing constant close apposition over the largest area of contact possible. 4) Prevention of shearing motion and the establishment of a hinge. Charnley felt that shearing motion was the worst of all movements in that it disturbed the surfaces equally throughout their area of contact. Angulatory movements, if they occurred at a hinge sited at a constant point, disturbed healing points distant to the hinge but very little at points near it. With the joint under continuous compression, shear was eliminated and movement was trans-lated into an angulatory motion. The hinge site became the bridgehead for osseous union. The hinge would occur on one side of the joint because the compression rarely occurred exactly in the center axis of the joint. This observation is again related to the tension band principle (Muller et al., 1970). Thus continuous compression would change shear motion into a flexible bridgehead for osseous union to occur. Charnley felt that this was the most important mechanical factor that occurred from compression arthrodesis. This point also explained his observation that slight move-ment with compression would allow a bony union which was greater than that formed with immobilization alone. The biological factors that Charnley described were the following: 1) If very high mechanical pressures were involved osteoclasis would be a more prominent feature than osteogenesis. When pressure was first applied to a cut flat surface, tiny points would be exposed to high pressure which would collapse until an area of contact was achieved where the bone strength balanced the pressure applied. 2) In the range of pressures that Charnley used, he demonstrated that the greatest amount and density of new bone was at the point of greatest pressure and that the amount and density diminished where the pressure was less.

Charnley (1953) listed what he considered to be the criteria for an ideal arthrodesis using continuous compression. These are summarized as follows: 1) Avoidance of neurovascular structures. 2) Exclusion of normal joints from the compressive force. 3) The line connecting the two points through which pressure was applied should pass through or very near to the axis of the joint to be arthrodesed. Angulation forces were controlled by excision of the articular bone ends to form plain surfaces and the achievement of a wide base of contact. Where the line of compression was more to one side of the joint, the joint became more stable against angulation in one direction. In joints with angulation forces in only on direction, this principle could be used to the surgeon's advantage. 4) A normal blood supply had to be present at the articular surface and at least parts of the apposing bone ends had to be free of active disease. Charnley felt that the blood supply for bone grafts was very important and thus bone grafts should be placed as far as possible to the outside of the articulation and should not separate living cancellous bone over the entire area. 5) Destruction of the natural center of motion, establishment of "bone blocks" and the development of fibrous ankylosis as a second line of defense. Charnley felt that there were two possible types of fibrous ankylosis. The first type was a painless type where there was close apposition of the bone ends. He felt that this was the type that followed destructive joint disease. The second type was associated with pain. This type was produced when slight movement was present and had the tendency to create a deformity later in the course of events. Because fibrous scar tissue has the characteristic of being able to bend but not stretch, bones which touched over two or more points would resist movement more than those which had contact over a very small surface. Charnley described this as a "bone block" or the utilization of wide area

bone contact to enhance the chance of producing a painless fibrous union, if an osseous union did not occur. 6) Charnley felt that high compression forces and spring resilience were necessary. He felt that without this, the compression would work loose. Small areas of high pressure would crumble and this would produce slight movement. However, with a spring in the system the compression was maintained. 7) External splints were used to minimize angulatory movement. As a general rule, Charnley dispensed with splinting two months postoperatively if the arthrodesis was clinically solid. Charnley did not feel that it was important to wait for radiographic evidence of realignment of the trabeculation as an indication of an osseous union. He felt that appearance of sclerosis at the arthrodesis line indicated a fibrous union, whereas abscence of sclerosis several months after the operation implied an osseous union.

Since Charnley's treatise a great deal of research has been performed on the compression healing of fractures and the use of bone grafts. This information has modified the explanation of compression arthrodesis and the approach to compression arthrodesis as well. Perren et al (1969) compared the response of osteotomized tibias to unaltered tibias under static compressive forces. They showed a similar decrease of compressive forces between unaltered and osteotomized tibias. This rate of decrease did not depend on the amount of compression present initially. Healing of osteotomized tibias revealed a lack of interposed fibrous tissue or cartilage and a lack of external callus. Histological sections demonstrated that primary bone union can occur under the proper conditions. Perren's data indicated that at pressure levels of up to 140 kilograms no necrosis was present at the bone interfaces or at the screw sites. There was a similar decrease of compression in unaltered as well as in osteotomized

tibias, indicating that the rate of change of pressure did not depend on any
factor peculiar to the osteotomized tibia. This finding was probably related
to the functional adaption of bone structure to stress according to Wolff's
law and thus due in fact to haversian remodelling. Their data clearly
demonstrated that static pressure, as long as it was rigidly fixed, did not
necessarily induce pressure necrosis. However they felt that motion and infec-
tion could induce bone resorption. Slight degrees of motion at the apposing
surfaces were probably the cause of necrosis which had been previously
blamed on pressure. Rhinelander et al (1968) demonstrated the importance
of good vascularity in the healing of a fracture. They stated that the
normal medullary circulation supplies the inner two-thirds to three-quarters
of the cortex. Rhinelander was able to show that the endosteal callus
contributed to the earliest osseous union of any significance. In order for
endosteal new bone formation to occur, immobilization was necessary to allow
the endosteal capillaries to cross the fracture site. Even so, endosteal
capillaries were inhibited in the early stages of healing by the presence
of a hematoma between the apposing surfaces. Any delay in the progression
of these endosteal vessels resulted in a delayed union which was associated
with large masses of external callus. Regardless of the speed of healing,
deposits of fibrocartilage were found in the external callus. As this
callus became more osseous it was observed that a coinciding increase in blood
supply from the medullary vessels occurred. The rapidity with which the
intramedullary blood flow could be established was demonstrated by Lemperg
and Arnoldi (1970). They were able to demonstrate that between twenty
minutes to three hours after completion of an arthrodesis of plane cancellous
bone surfaces, some venous return through intramedullary vessels occured.
Stringa (1957) in his studies of the vascularization of bone grafts

determined that there was a striking correlation between the rate of vascular penetration of the bone grafts and their eventual incorporation into the osseous bed. His study illustrated that a cancellous bone graft was most rapidly vascularized in comparison to all other types of bone grafts available. Stringa found that an autogenous cancellous fragment five millimeters thick could be completely vascularized in twenty to twenty-five days. However he found that obstacles such as a thin cortex or articular cartilage could greatly delay the vascularization of the bone graft. It was found that the presence of cartilage across the line of vascular penetration would delay further vessel migration for at least thirty days, and then only isolated vessels were found. Reynolds and Oliver (1950) attempted to determine whether bone grafts had any capacity of regeneration or whether they were entirely replaced by elements of the host. In their studies they observed no evidence that any elements of the bone graft retained osteogenic powers. The bone graft was incorporated into the host bone by appositional growth of the host. However Campbell et al (1974) demonstrated histologically that osteogenic cells and osteocytes would survive in fresh autogenous bone grafts. The osteogenic activity was found to take part in the incorporation of the graft into the host tissues. Heslop et al (1960) agreed with these results, demonstrating that osteocytes near the outer surface of autogenous bone grafts would survive.

The accumulation of this information revolutionized concepts of fracture repair and set the stage for a number of Swiss orthopedic surgeons to develop the ASIF[1] technique for rigid internal fixation of fractures. Muller et al (1970) have stated the basic principles of the ASIF technique as it applies to the compression healing of fractures. These are as follows: 1) The reaction of bone to metal implants. With use of ASIF technique and ASIF

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[1]ASIF – Association for the Study of Internal Fixation.

implants, no toxic effects are seen in directly adjacent bone and no damage occurs in the placing of these implants into bone. 2) When two vascular bone fragments are rigidly fixed under compression so that no shearing or torsional forces can act, no resorption of the fragments takes place, but direct bony union occurs without any radiologically visible periosteal or endosteal callus. 3) As long as the bone is not devitalized and the fragments are rigidly fixed, resorption and bone formation occur simultaneously. 4) Under favorable biological and mechanical conditions the pressure between fragments diminishes very slowly. The mechanical advantage of compression can be used without biological disadvantage, and in fact the compression greatly increases the rigidity of internal fixation. 5) The development of a standard bone instrument set. 6) The AO[1] documentation center records the successes and failures of a specific technique, which allows modifications to be made where necessary and to document success with a certain technique. Muller et al (1970) describe the surgical technique involved in the arthrodesis of numerous joints. The technique involves the creation of a fresh fracture by osteotomizing the two apposing articular surfaces and then achieving a compression fixation using the ASIF technique.

Whittick (1974) has summarized the generally accepted mode of action of autogenous cancellous bone grafts. These are as follows: 1) Transplanted autogenous cancellous bone will contribute to the formation of new bone at the site. Some osteocytes do survive and participate in the formation of new bone. 2) Bone grafts provide a scaffolding and become involved in the revascularization process that precedes resorption and replacement with new bone. 3) Bone formation at the graft site is not dependent on the survival of graft osteocytes. 4) The graft material may provide factors necessary for

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[1]AO – Arbeitsgemeinschaft für Osteosynthesefragen

the "induction" of osteogenesis. 5) Cancellous bone grafts have the characteristic of being composed of thin trabeculae and large vascular channels which permit rapid revascularization and profuse contact with tissue fluids.

6) Small fragments of cancellous bone especially from a young donor allow a more rapid rate of revascularization, resorption, and replacement by new bone than do larger graft fragments from an older donor. 7) Bone grafts provide usable mineral and matrix ingredients which can be utilized in the laying down of new bone. Bone grafts are indicated in assisting the healing of fractures that have a large defect and in assisting in the arthrodesis of a joint.

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ADDITIONAL RESULTS

1. Radiographic and Clinical Signs.

Horse #1 -- a seven year old 350 kilogram grade mare.

The screws were well placed and good compression was achieved. On day 15 there was a very slight halo of lysis around the cancellous bone graft. There was a slight calcification of the extensor tendon at its insertion. The joint space was only visible in the palmar one-third of the joint. On day 27 the mare was euthanized because of a perforated gastric ulcer.

Horse #2 -- a four year old 450 kilogram grade gelding.

The screws were well placed and good compression was achieved. On day 21 the cancellous bone graft was homogeneously dense. On day 47 there was a halo of lysis around the cancellous bone graft and in the cancellous bone surrounding the screws in the distal phalanx. Calcification was present in the extensor tendon and in the collateral sesamoidean ligaments of the navicular bone. Pedal osteitis was present. On day 63 the entire bone graft was lytic. Lysis was present around the medial screw in the distal phalanx only. The lysis in the distal phalanx, the calcification in the extensor tendon, and the calcification in the collateral sesamoidean ligaments of the navicular bone were less than previously described. There was a slight increase in the degree of pedal osteitis. On day 113 there was a total lucency at the site of the bone graft and the adjacent middle and distal phalanges. The joint space was greatly narrowed dorsally and palmarly to the zone of lysis. The zone of lysis around the medial screw was unchanged. The calcification in the extensor tendon was again prominent. Very little external callus was present. The gelding would bear weight on the limb but was still quite lame.

Horse #3 -- a two year old 300 kilogram grade mare.

The cortex of the middle phalanx lacked sufficient strength so that when the lateral cancellous screw was tightened, the head of the screw pulled through the cortex and into the center of the second phalanx. On day 14 there was an area of lysis around the lateral screw head. The cancellous graft was homogeneously dense. On day 34 the dorsal two-thirds of the joint space was no longer visible. The cancellous graft, the distal palmar border of the middle phalanx, and the distal articular border of the navicular bone were lytic. A purulent discharge was present in the hoof defect and in the stab incision over the lateral screw. The mare was placed on broad spectrum antibiotics. The foot was soaked in magnesium sulfate solution, and the cast was taped back on the limb between treatments. On day 40 the dorsal portion of the joint appeared to be filled with material of the same density as bone. The lysis in the palmar portion of the joint was more pronounced. The navicular bone had shifted slightly proximally. Day 48 revealed lysis around the medial screw. There was an increased amount of lysis of the navicular bone, the distal palmar portion of the middle phalanx, and the proximal palmar portion of the distal phalanx. A periosteal proliferation was present on the distal dorsal portion of the middle phalanx and the extensor process of the distal phalanx. On day 68 the total joint space was visible. There was a great increase in the previously reported periosteal reaction. The entire lateral screw and the threads of the medial screw were surrounded by a zone of lysis. The head of the medial screw had backed away from the middle phalanx. The deficit in the palmar half of the joint was becoming more radiodense. The navicular bone was involved in this bony callus. A draining tract extending from the defect in the hoof wall up to the coronary band was visible. A

subsolar abscess was present. On day 82 a progression of the previous changes was seen. The joint space was wider, the periosteal proliferation had increased, and the lysis around the lateral screw had increased. The first phalanx was osteoporotic. By day 95 these changes had progressed further. On day 103 the lateral screw was removed. On day 112 a zone of lysis could be seen where the lateral screw was removed. The mare was very lame at this time and preferred to stand three-legged. On day 122 the mare was euthanized.

Horse #4 -- a ten year old 450 kilogram grade mare.

The removal of articular cartilage was carried too far dorsally resulting in a weakening of the extensor process. The screws were well placed and good compression was achieved. On day 16 there was a very slight halo of lysis surrounding the cancellous graft. A small area of calcification was present in the soft tissue on the dorsal surface of the joint. On day 47 some dorsiflexion had occurred in the distal inter-phalangeal joint. This forced the heads of the screws away from the cortex of the middle phalanx. There was an extensive periosteal proliferation on the entire dorsal surface of the middle phalanx and the proximal dorsal one-half of the distal phalanx. Calcification was present in the extensor tendon at its insertion on the distal phalanx. There was complete lysis of the bone graft and the adjacent middle phalanx. On day 98 the periosteal reaction was less active but still active at the joint margins. The joint was filling in with bony callus. The lysis in the palmar one-half of the joint was now involving the articular surface of the navicular bone. Some lysis was present around the screw shafts. The cast was removed. On day 123 the periosteal reaction was restricted to the dorsal surface of the

joint. There was new bone growth on all surfaces of the navicular bone except the flexor surface. The density of the material in the joint was slightly increased. There was less of a lytic zone around the screw shafts. The mare would bear weight on the limb but was still quite lame.

Horse #5 -- a five year old 450 kilogram grade gelding.

The screws were well placed and good compression was achieved. On day 24 the graft was homogeneously dense. There was some calcification within the extensor tendon. On day 46 there was a slight halo of lysis around the bone graft. There was a periosteal reaction on the dorsal distal one-half of the middle phalanx and an increased amount of calcification in the extensor tendon. On day 73 there was sclerosis of the apposing subchondral bone of the middle and distal phalanges. The bone graft appeared slightly more lytic. All of the phalanges were osteoporotic. The cast was removed. On day 93 the bone graft appeared to be of the same density as the middle phalanx and appeared incorporated with it. The joint space was slightly wider than previously. The periosteal proliferation was increased and a slight periosteal reaction was present on the palmar distal portion of the middle phalanx. On day 185 there was an extensive periosteal reaction on the entire dorsal surface of the middle phalanx and the proximal dorsal surface of the distal phalanx. The dorsal joint space was obliterated and the remainder of the joint was filling in with radiodense material. The navicular bone had undergone few changes. The gelding would bear weight on the limb but was still very lame.

Horse #6 -- a four year old 450 kilogram grade gelding.

The screws were well placed and provided good compression. On day 21 there was a halo of lysis around the cancellous bone graft. There was

also lysis of the flexor surface of the navicular bone. On day 44 there was a total lysis of the bone graft. A periosteal proliferation was present on the dorsal surface of the middle phalanx and the extensor process of the distal phalanx. The navicular bone was entirely lytic. On day 62 the periosteal reaction was more pronounced. The lysis at the site of the bone graft had extended into the middle and distal phalanges and into the navicular bone. On day 71 there was sclerosis of the apposing subchondral bone of the middle and distal phalanges and the navicular bone. There appeared to be a bony union of the navicular bone with the middle and distal phalanges. The lysis in the joint space was less but still involved the distal middle phalanx. On day 85 the proximal phalanx appeared osteoporotic. The cast was removed. On day 98 there was a slight increase in the width of the joint space and a slight increase in the periosteal reaction. On day 190 the joint space had widened so that the previous union of the middle phalanx with the navicular bone was separated. The periosteal reaction on the dorsal middle phalanx and the extensor process of the distal phalanx had increased. There was no pedal osteitis or lysis around either of the screws. The gelding would bear weight on the limb but was still very lame.

Horse #7 — a two year old 300 kilogram grade mare.

The screws were well placed and achieved good compression. The threads of the lateral screw were very close to the solar canal. On day 23 there was a slight halo of lysis around the bone graft. The vascular channels were more pronounced. On day 40 the zone of lysis around the bone graft was larger. The entire joint space appeared irregular. On day 60 the joint had undergone a slight degree of dorsiflexion. This forced the heads

f both cancellous screws away from the cortex of the middle phalanx. In
he dorsal portion of the joint the middle and distal phalanges were in
pposition. There was complete lysis of the bone graft with involvement
f the articular surface of the navicular bone. There was lysis around
oth screws with the shafts being primarily involved. On day 87 the degree
f dorsiflexion had increased. There was a periosteal reaction on the
lorsal distal portion of the middle phalanx and the extensor process of
he distal phalanx. The cast was removed. On day 98 there was a slightly
ncreased degree of lysis in the joint space. On day 195 there was a
larked periosteal new bone growth on the dorsal middle phalanx and the
xtensor process of the distal phalanx. A periosteal proliferation on
he palmar aspect united the navicular bone with the middle and distal
halanges. The entire joint space was still evident. The apposing surfaces
f the middle and distal phalanges were sclerotic. No pedal osteitis was
resent. The mare would bear weight on the limb but was still lame.

lorse #8 — a four year old 350 kilogram grade mare.

The screws were placed in the proper position but a slightly longer
screw length would have put less stress on the junction of the thread and
he shaft of the screw. A pedal osteitis was present. On day 16 the
one graft appeared homogeneous. On day 35 the entire dorsal surface of
the middle phalanx and the extensor process of the distal phalanx had a
eriosteal proliferation. There was a periosteal reaction on the palmar
listal portion of the middle phalanx as well. The graft site was becoming
lytic and the pedal osteitis was becoming more extensive. Because of a
mild fever and the radiographic signs, an infection was suspected. The
mare was placed on broad spectrum antibiotics and the foot was soaked

aily in a magnesium sulfate solution. The cast was taped back on the imb for support after each treatment. On day 48 the joint space was arrowed dorsally. The periosteal reaction and density of bone in the raft site had both increased. There was lysis around the screw threads f the medial screw. On day 64 there appeared to be bony union. A zone f lysis was present around the screw threads and the shaft of the medial crew. The cast was removed. Some purulent discharge was present at both kin incisions. By day 78 there was more lysis in the joint space. Both crews were surrounded by zones of lysis over their entire length. Both crews were surgically removed. On day 98 lytic zones were present where he screws were located. The navicular bone had collapsed on its distal argin. On day 114 the lytic areas in the middle and distal phalanges ere filling in. More of a bony callus was present between the navicular one and the middle phalanx. On day 141 there was no change in the appearnce of the joint space but the periosteal proliferation had increased. On ay 197 there was still a zone of lysis in the joint space. The dorsal callus id not involve the proximal interphalangeal joint. Sclerosis of the pposing bone ends of the middle and distal phalanges was present. The edal osteitis was very pronounced. The mare would bear weight evenly on he forelimbs but was still lame.

lorse #9 -- a twelve year old 450 kilogram thoroughbred gelding.

The screws were well placed and good compression was achieved. On lay 28 there was a slight halo of lysis around the bone graft. On day 66 :here was a periosteal proliferation on the dorsal distal portion of the iiddle phalanx and the extensor process of the distal phalanx. The cancellous ;raft, the flexor border of the navicular bone, and the articular border of

the navicular bone were lytic. There was a pedal osteitis and an increase in the size of the vascular channels present in the distal phalanx. The subchondral bone of the distal phalanx was sclerotic. The alignment of the middle and distal phalanges had undergone dorsiflexion forcing the heads of the cancellous screws away from the cortex of the middle phalanx. This produced a compression of the dorsal joint space. The cast was removed. On day 83 there was an increase in the periosteal proliferation. An additional periosteal reaction was present on the distal palmar portion of the middle phalanx. On day 95 the entire joint space was lytic and widened. A slight degree of lysis was present around the shafts of both screws. The entire periosteal proliferation had increased. On day 153 the joint space and the space around the screw shafts were filling in with radiodense material. The distal interphalangeal joint was dorsiflexed a slight degree more, which was producing a subluxation of the joint and a distal displacement of the navicular bone. The periosteal proliferation was still active. The proximal dorsal border of the middle phalanx was lytic. On day 202 there was a complete osseous union of the middle phalanx with the distal phalanx, with incorporation of the navicular bone in the callus. The subluxation of the joint had not progressed. The flexor surface of the navicular bone was quite rough. Some pedal osteitis was present. The gelding would bear weight on the affected limb but was lame. When standing, he would point the limb periodically.

Horse #10 -- a two year old 300 kilogram grade gelding.

When the lateral screw was tightened the head of this screw pulled through the cortex of the middle phalanx. A washer was placed on the screw, but the distal phalanx lacked sufficient holding power for the threads of

the screw. Another hole was drilled with similar results. Thus no cancellous screws were placed in the distal limb in this case. On day 22 the bone graft was homogeneously dense. A pedal osteitis was present. On day 57 the graft was still homogeneous and there appeared to be fusion of the middle and distal phalanges in the palmar one-half of the joint. There was a periosteal proliferation on both the dorsal and palmar aspects of the distal portion of the middle phalanx. The cast was removed. On day 74 there was lysis and widening of the joint space. There was sclerosis of points of the subchondral bone of the distal portion of the middle phalanx and the proximal portion of the distal phalanx. The periosteal proliferation was more pronounced. A cast was replaced on the limb. On day 128 the joint space was filling in with radiodense material but the sclerosis of the apposing bone surfaces was still present. The cast was removed. On day 233 the joint space was still present but was filling in with radiodense material. The callus that had formed had incorporated the navicular bone. The periosteal reaction on the middle phalanx was not as active and the pedal osteitis present was minimal. This gelding would gallop in a pasture and show only a slight lameness.

Horse #11 -- an eight year old 500 kilogram grade mare.

The surgical placement of the medial screw was angled slightly more dorsally than desired but did not perforate the dorsal surface of the distal phalanx. On day 14 no radiographic change was visible. On day 28 a periosteal reaction was present on the dorsal surface of the middle phalanx. The cancellous bone graft appeared to be continuous with the middle and distal phalanges in the palmar aspect of the joint. Some lysis was present around the screw threads. On day 36 the periosteal reaction on the dorsal

surface of the middle phalanx was more pronounced. There was filling of the dorsal portion of the joint with radiodense material. The area of the joint where the majority of the bone graft was placed showed an increased lucency. Some lysis was present around the shaft of the lateral screw. On day 47 the lysis was more pronounced. The distal margin of the navicular bone was involved in this lytic process. In the dorsal portion of the joint there appeared to be a bony union. The flexor surface of the navicular bone was sclerotic. On day 55 the flexor surface of the navicular bone showed roughening. The cast was removed. On day 90 the lysis in the joint had spread dorsally. The periosteal reaction was much more pronounced on the middle phalanx. Calcification was present in the collateral sesamoidean ligaments of the navicular bone. Day 102 revealed that the graft site was becoming more dense. The new bone growth between the middle phalanx and the navicular bone was increasing in density and size. On day 238 there was a homogeneous bone density from the middle to the distal phalanx. The navicular bone was incorporated in the bony callus and had changed shape completely. The lysis around the screw threads had not changed since day 28, and the lysis around the shaft of the lateral screw had filled in. A bony spur was present in the joint capsule attachment on the proximal portion of the middle phalanx. No pedal osteitis was present. The mare would bear weight on this limb but was lame.

Horse #12 -- a four year old 350 kilogram grade gelding.

The removal of articular cartilage was taken too far dorsally, resulting in a weakening of the extensor process of the distal phalanx. The screws were placed in such a manner that the center of the cross formed by the two screws was on the medial side of the joint. The screws in this case

were in the palmar half of the joint. Because this would apply a tension band to the joint, the dorsal surface would be under an additional compressive force when weight was borne on this limb. Surgical radiographs revealed an old but active periostitis at the attachment of the middle distal sesa- noidean ligament. The cancellous bone graft could be seen as a homogeneous radiodense mass filling the palmar one-half of the joint. On day 27 radiographs revealed a periosteal new bone growth on the distal palmar aspect of the middle phalanx adjacent to the navicular bone. The bone graft appeared to be less dense than was previously noted. On day 37 the extensor process was fractured where it had been weakened during surgery. This allowed the screw heads to move away from the cortex of the middle phalanx. The new bone growth continued to increase between the middle phalanx and the navicular bone. New bone growth was present at the attachment of the joint capsule on the middle phalanx. The bone graft continued to decrease in density. On day 59 the extensor process showed evidence of healing to the distal phalanx. In the palmar one-half of the joint a lucent area was obvious where the bone graft had been placed. The cast was removed. On day 71 the navicular bone had a sclerotic flexor border and the bone was changing shape so that it was flattened in its articular-flexor width. The medial screw showed lysis around the screw threads and the shaft. Neither screw head appeared to have moved any further away from the cortex of the middle phalanx. On day 113 the healing of the extensor process was complete. A pedal osteitis remained on the dorsal surface of the distal phalanx where the fracture line had emerged. There was sclerosis of both the middle and distal phalanges adjacent to the joint. The joint space had widened. Lysis was now present around the shaft of the lateral screw as well. The

periostitis on the dorsal distal portion of the middle phalanx and on the extensor process of the navicular bone was more pronounced. On day 152 the horse became acutely lame. Heat and swelling were present over the proximal phalanx adjacent to the previously described bony production at the attachment of the middle distal sesamoidean ligament. On day 261 there appeared radiographically to be a complete bony ankylosis. The periostitis appeared less active. Less of a lytic zone was present around both screws. Pedal osteitis was still present on the dorsal surface of the distal phalanx at the distal end of the fracture site. An old but active periosteal reaction was present on the proximal phalanx at the attachment of the collateral ligaments of the proximal interphalangeal joint and at the attachment of the middle distal sesamoidean ligament. The diaphysis of the proximal phalanx was sclerotic and lytic. The entire shape of this portion of the proximal phalanx appeared to be changing. At this time the gelding would bear even weight on his forelimbs but was nodding lame on the affected limb at a trot.

2. Histopathology

Horse #1 -- 27 days post surgery

The remaining articular cartilage was frayed and splintered and was becoming more eosinophilic. The bone graft was dead and showed no osteoblastic or osteoclastic activity. Some old hemorrhage was present in the marrow cavity adjacent to the location where all articular cartilage had been removed.

Horse #2 -- 113 days post surgery

No articular cartilage was present. A great deal of fibrous tissue was present in the joint space. The cancellous bone graft had sequestered and was surrounded with foreign body giant cells, macrophages and a sprinkling of polymorphonuclear cells. The deep flexor tendon and the cartilage on the flexor surface of the navicular bone were normal.

Horse #3 -- 122 days post surgery

The joint space was filled with dense well vascularized fibrous tissue. Islands of eosinophilic articular cartilage and sequestra of bone graft were present in the joint space. These sequestra were surrounded by foreign body reaction with many active giant cells present around the pieces of bone graft. Numerous polymorphonuclear cells were present in the joint space and in the screw canals. The bone adjacent to the fibrous tissue in the joint space was very active, with osteoblasts being more prominent than osteoclasts. The flexor surface of the navicular bone had degenerating cartilage which was being replaced with fibrocartilage. The latter was uniting the deep flexor tendon with the navicular bone.

Horse #4 -- 123 days post-surgery

The screw canals had a sprinkling of polymorphonuclear cells interspersed in the fibrous tissue present. Hemosiderin-laden macrophages were

present within the joint space. Some cancellous bone graft fragments were surrounded by fibrous tissue and others were surrounded by thick layers of osteoblasts. The cartilaginous flexor surface of the navicular bone was destroyed. There was a chronic tendonitis of the deep flexor tendon as it passed over the navicular bone.

Horse #5 — 185 days post-surgery

An osseous union was present uniting the middle phalanx with the distal phalanx. Islands of degenerated articular cartilage were present. Other areas within the joint space revealed a cartilaginous callus which was being ossified. The bone graft was dead but had new bone production at its periphery.

Horse #6 — 190 days post-surgery

The remaining articular cartilage was degenerating. A layer of fibrous tissue was present adjacent to the bone ends, separating the cancellous bone graft from healthy cancellous bone. No osteoblastic or osteoclastic activity was present in this graft. Osteoblastic activity was marked surrounding the fibrous tissue around the shaft of the cancellous screws.

Horse #7 — 195 days post surgery

The screw canal was filling in with cartilaginous callus. The joint cavity was filled with degenerate bone graft of homogeneous pink color. Some bone graft fragments were surrounded by a thin layer of granulation tissue. A callus was produced, consisting of cartilage and new bone, which united the middle and distal phalanges. The cartilage of the flexor surface of the navicular bone was destroyed.

Horse #8 -- 197 days post-surgery

Within the joint cavity debris was surrounded by cartilaginous callus. Areas were present where a bony callus almost bridged the joint cavity. The articular cartilage on the flexor surface of the navicular bone was slightly frayed.

Horse #9 -- 202 days post-surgery

Hemosiderin-laden macrophages were present in the fibrous tissue in the screw canal. The joint space was filled with dead cancellous bone graft which was surrounded by active osteoblasts and osteoclasts. No remnants of articular cartilage were present. The articular cartilage on the flexor surface of the navicular bone had degenerated.

Horse #10 -- 233 days post-surgery

No remnants of articular cartilage were present. A very narrow layer of cartilaginous callus separated the bony surfaces of the middle and distal phalanges. Ossification of this cartilaginous callus was occurring. The deep flexor tendon and the articular cartilage on the flexor surface of the navicular bone showed no pathological changes.

Horse #11 -- 238 days post-surgery

A cartilaginous callus was present in the joint space. The cancellous bone graft was intermixed in this cartilaginous callus. Portions of this bone graft were surrounded with osteoblasts. The articular cartilage on the flexor surface of the navicular bone had degenerated and was united with the tendon of the deep digital flexor.

Horse #12 -- 261 days post-surgery

Layers of cartilaginous callus were present surrounding the homogeneous degenerated cancellous bone graft in the center of the joint cavity. The navicular bone had no pathological changes.

3. Review of Cases of Osteoarthritis of the Distal Interphalangeal Joint

The medical records and radiographs at Dykstra Veterinary Hospital, Kansas State University, were reviewed from 1967 to 1976. During this time period 85 equine cases of osteoarthritis of the distal interphalangeal joint were diagnosed radiographically. The ages of these horses at the time of examination ranged from 7 days to 20 years, and the average age was 8 years. However, many horses had histories of clinical signs being present for lengthy periods. The breed and sex distributions are indicated in Table 1. The great majority of the stallions involved were young animals. The osteoarthritis in many of these cases was secondary to lacerations. The etiologies of osteo- arthritis of the distal interphalangeal joint varied with the age of the horse (Table 2). Although the number of cases reported under 1 year of age was very small, all of these were infectious in nature. In the 1 to 4 year old range the most common cause was laceration to the soft tissue of the pastern (7/12 cases). All of the lacerations, punctures, and infections secondary to trauma, when added together, account for 12/19 of the cases. The 5 to 8 year old range still has a significant number of cases secondary to lacerations (7/26). Chronic laminitis has a higher incidence in this age range (4/26) than in the younger ages. However, a category of "unknown etiology" has now become very prominent (10/26). The 9 to 12 years of age range has an even higher proportion (12/26) of distal interphalangeal osteo- arthritis of unknown etiology, and the last age range of 13 years and older has a higher proportion yet (7/12).

Of the 85 cases reviewed, 33 developed with an insidious onset and with no known cause at the time of examination. Table 3 lists other radiographic lesions that were present with osteoarthritis of the distal interphalangeal

oint in these 33 cases. A high proportion of these cases (24/33) had other

athological lesions that were associated with an increased concussion to

:he distal limb (navicular disease, sidebone, high ringbone, pedal osteitis).

i4/85 cases had osteoarthritis of both the proximal and distal interphalangeal

:oints. Table 4 indicates the limb incidence in these 85 cases. It should be

toted that in numerous cases only the limb with the obvious lameness was

·adiographed. However, osteoarthritis of the distal interphalangeal joint

.s more common in the front limbs than in the hind limbs.

The radiographic findings in these 85 cases are varied from very minor

:o very severe. Numerous cases had several sets of follow-up radiographs.

'his permitted re-examination of debatable lesions for progression at a later

late. Osteoarthritis of the distal interphalangeal joint was an incidental

:adiographic finding on numerous occasions when radiographs were taken for

;ome clinically more obvious accompanying lesion. Thus there was no specific

miform radiographic series for evaluation on all of these cases. Numerous

:ases had a navicular series consisting of a lateral, an anterior-posterior

lorsal-ventral oblique, and a posterior-anterior dorsal-ventral oblique to

lemonstrate the flexor surface of the navicular bone. The remainder had only

in anterior-posterior view and a lateral view. In contrast to evaluation of

:he proximal interphalangeal joint in which the anterior-posterior view is

nost informative, the lateral view is most demonstrative in displaying

;ubtle changes in the distal interphalangeal joint. All of the lateral radio-

;raphs had been taken with the limb non-weight bearing to allow the foot to

oe included in the views. Thus it is impossible to evaluate narrowing of

the joint on these radiographs. The obvious radiographic findings were:

1. Periosteal proliferation on the distal end of the middle phalanx.

In specific cases this new bone growth was observed on all surfaces. However, involvement of the dorsal surface was much more common.

2. Periosteal proliferation on the extensor process of the distal phalanx.

3. Osteophyte production on the extensor process of the distal phalanx.

4. Rarely a roughening of the distal articular surface of the middle phalanx was observed on the anterior-posterior or anterior-posterior dorsal-ventral oblique views.

5. Occasionally a sclerotic line was present in the subchondral bone of the middle phalanx adjacent to the articular surface.

6. With the very chronic proliferative cases the joint space could be partially filled with new bone.

In specific cases with either a chronic rotation of the distal phalanx or a subluxation of the distal interphalangeal joint (resulting from loss of support of the deep flexor tendon with the distal phalanx being displaced dorsally), the radiographic changes resulted from tearing of the joint capsule on the middle and distal phalanges. These signs consisted of osteophyte formation at the articular margins. With subluxation of the distal inter-phalangeal joint, abnormal stresses are placed on the navicular bone producing calcification within the collateral sesamoidean ligaments of the navicular bone. Usually an infectious process was also present in these cases producing much more of a periosteal proliferation on all bones involved in the infection.

When a chip fracture of the extensor process is present, the degree of osteoarthritis will depend on the chronicity of the lesion and the size of the chip. With avulsion of the extensor process some degree of osteoarthritis will occur as a result of the damage to the articular surface. If not reduced,

these avulsion fractures become non-union fractures. The accompanying
extensive periosteal proliferation on either side of the fracture extends
into the joint. The dorsal distal end of the middle phalanx will show
proliferative and degenerative changes as a result of the wear from the
roughened extensor process.

Cases with a chronically active high ringbone will have a periosteal
reaction on the middle phalanx. If the proximal interphalangeal joint does
not ankylose, the reactive periosteum on the middle phalanx will continue to
produce new bone in an attempt to ankylose this joint. This produces abnormal
stress on the joint capsule of the distal interphalangeal joint resulting
in the production of new bone on the extensor process.

When a laceration or puncture of the skin is followed by a chronic
septic wound, the periosteum associated with this chronic inflammation is
very reactive and will produce extensive new bone. The periosteum may be
injured with the original laceration or puncture. With proper treatment of
the infection the periosteal new bone growth is greatly limited.

When there were numerous follow-up films and the lesion was an extension
of a lesion originally proximal to the distal interphalangeal joint, the first
new bone growth was usually somewhat removed from the articular surface.
Unless the cause for the inflammatory process migrating distally was halted,
this calcification would extend towards the joint until new bone growth was
present at the articular margins. The original calcification presumably
impaired the mobility of the joint by interference with the movement of the
soft tissue. This would lead to abnormal wear of the joint and osteophyte
production at the joint margin.

It is very difficult to distinguish between a normal prominence of the
extensor process and what may be the early stages of osteophyte production of
the extensor process. A true lateral radiographic view is essential. With

ost osteophytes there will be a slight palmar deviation at the tip of the

xtensor process which will narrow the joint at this location. This was the

irst radiographic lesion in all cases of osteoarthritis of the distal inter-

nalangeal joint that were examined radiographically as they progressed.

ubsequently the extensor process would develop more new intra-articular

one.

Table 1

BREED AND SEX DISTRIBUTION OF OSTEOARTHRITIS OF

THE DISTAL INTERPHALANGEAL JOINT

Breed	Number
Quarter Horse	57
Paint	2
grade	2
Thoroughbred	15
mule	1
Morgan	2
Arabian	1
Tennessee Walker	1
Appaloosa	2
Clydesdale	1
Palomino	1
	85

Sex	Number
female	25
male	12
male castrate	48
	85

Table 2

Etiology	Ages in Years				
	less than 1	1 to 4	5 to 8	9 to 12	13 and older
Damage to deep flexor tendon allowing sub-luxation of distal interphalangeal joint	1	2			
Laceration of soft tissue of pastern		7	7	3	1
Fractured middle phalanx		1	1	1	
Chronic septic wound following trauma		1		1	
Secondary to subluxation of proximal interphalangeal joint		1			
Secondary to chronic distal phalanx rotation		1	4	1	3
Infectious arthritis	1	1	1		
Secondary to sole penetration		1	1	5	
Fractured extensor process			1	2	1
Secondary to hoof crack			1		
Blunt trauma				1	
Unknown		4	10	12	7
TOTAL	2	19	26	26	12

Table 3

Pathological Lesion	Number
Navicular Disease	9
Sidebone	2
High Ringbone	9
Navicular Disease & Sidebone	2
Navicular Disease & High Ringbone	1
Navicular Disease & Sidebone & Pedal Osteitis	1
No other lesions	9
	33

Table 4

Limb	Number of Cases
Right Front	35
Left Front	14
Right and Left Front	20
Right Hind	11
Left Hind	5
	85

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SURGICAL ARTHRODESIS OF THE DISTAL INTERPHALANGEAL JOINT IN

A HORSE

by

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B.Sc. University of Calgary, 1970

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Osteoarthritis of the distal interphalangeal joint (low articular ringbone, low true ringbone, pyramidal disease) is a pathological condition that has been recognized in horses for many years. Veterinarians have not been successful in developing a treatment for the relief of the pain associated with this condition. In human orthopedic surgery, prior to the development of prosthetic joints, arthrodesis was common surgical treatment of osteoarthritis. Only recently has surgical arthrodesis been a treatment for osteoarthritic joints in veterinary medicine. However it has been recognized that ankylosis of the distal interphalangeal joint will occur in some equine cases of osteoarthritis of this joint. With this ankylosis, the painful lameness disappears. Thus it would seem feasible that surgical arthrodesis of the distal interphalangeal joint could be a treatment for osteoarthritis of this joint.

In this study a surgical technique was devised for compression arthrodesis of the distal interphalangeal joint. The articular cartilage was removed through a window produced in the hoof wall. The joint was packed with a cancellous bone graft taken from the tuber coxae. A large C-clamp drill guide was developed to aid in the precise placement of the cancellous bone screws. These were placed in a cruciate fashion through stab incisions proximal to the coronary band. This allowed compression fixation of the middle to the distal phalanges. The limb was placed in a cast following surgery.

The surgery was performed on twelve horses. These were necropsied and examined at times ranging from 27 to 261 days post surgery. Histologically all twelve horses had various stages of osseous ankylosis. A degree of delayed union was present in all cases. This delayed union appeared to be due primarily to movement. The compression achieved with this technique was not sufficient to resist micromovement and was especially susceptible to

torsional forces. The method of removal of articular cartilage through a small window in the hoof wall was not adequate. The articular cartilage that remained prevented a primary bone union from occurring between the middle and distal phalanges and impaired the vascularization of the cancellous bone graft. Infection contributed to the production of a delayed union in a few cases.

In all twelve horses a degree of lameness was present at the termination of the experiment. In some cases this could be explained by the lack of osseous union. In all cases an external callus was produced. The pressure that this applied to the inner sensitive structures of the hoof could have contributed to lameness in some cases. In 6 of the 12 horses navicular disease was present at the time of post mortem examination. A better understanding is necessary of the changes that occur in the biomechanics of the navicular bone when the distal interphalangeal joint is ankylosed.

Although it is possible to arthrodese the distal interphalangeal joint, the resulting lameness suggests that this technique is not satisfactory as a treatment for osteoarthritis of this joint.