Comparison bone plating - Richards vs. A.S.I.F.

by

William D. Hoefle

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INTRODUCTION

In recent years compression bone plating has gained popularity as a method for internal fixation of long bone fractures in small animals. Compression plating of fractures has several advantages over other methods of fracture fixation.

Anderson (1965) felt that compression was beneficial because it increased the rigidity of fixation by impacting the bone ends and narrowing the space between the fragments which had to be bridged by new bone.

Jacobs and Guten (1967) observed the same characteristics with compression plating. Additionally, they felt that compression plating permitted early ambulation, reduced muscle atrophy, and shortened the period of disability. Burwell (1971) agreed on these points and further felt that plating led to less deformity.

Wolff (1972) stated that compression plating permitted primary bone union which was accomplished when two vascular bone fragments were rigidly fixed under compression. Direct bony union occurred without radiologically visible callus.

Two major orthopedic companies, Richards[1] and A.S.I.F. (Association for the Study of Internal Fixation)[2] have devel-

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[1]Richards Manufacturing Co., Memphis, Tennessee.

[2]Association for the Study of Internal Fixation equipment distributed by Smith Kline Surgical Specialties, Philadelphia, Pennsylvania.

oped equipment to accomplish compression bone plating. Although the basic concept and principles of compression fixation are the same, each company utilizes different types of equipment and techniques.

Many veterinary surgeons have utilized one type of equipment or the other without a more valid reason for choosing other than which company was the better salesman. Granted, there may be differences in costs of equipment, but this may not be the best criterion for selection.

There are two basic differences between the systems. The Richards system utilizes screws which are self-tapping while the A.S.I.F. system does not. In the A.S.I.F. system the threads are cut into the bone with a tap before the screw is inserted. The Richards system uses a compression device which is applied over the bone plate utilizing an existing screw through the plate. The A.S.I.F. compression device is applied at the end of the plate and requires that an additional hole be drilled beyond the plate.

The purpose of this investigation was to compare healing of femur fractures repaired with Richards and A.S.I.F. equipment and to compare the holding effectiveness of the self-tapping with that of the non-self-tapping bone screw. The short and long term effects of the respective plates and screws on the bone and surrounding tissues were evaluated to help determine if there were adverse effects from leaving bone plates in place indefinitely. Evaluations and comparisons

were made by the use of clinical, radiological, gross, and histopathological studies.

LITERATURE REVIEW

In 1943 Urist and Johnson presented some classic observations of fracture healing in man. They stated that there was complete similarity in the general pattern of bone repair in man and animals. The gross structure of this pattern included three types of tissue - granulation tissue, fibrocartilage, and bone.

Procallus was a term applied to the organizing hematoma and highly vascular granulation tissue which developed in the first weeks of healing. The undifferentiated connective tissue cells exhibited the ability to differentiate into fibrocartilage callus - a translucent mass of dense fibrous connective tissue, fibrocartilage, and cartilage which was seen from the second to the third week of healing until the time of union.

The bony callus originated in some fractures as early as the first week, through the proliferation of spindle shaped cells in the inner layer of the periosteum and the endosteum of the fracture ends. These cells then became recognizable as osteoblasts and deposited new bone on the medullary and periosteal surfaces of the injured cortex. At about three to four weeks, the new bone grew from the endosteal and subperiosteal bony callus into the fracture gap by replacing the fibrocartilage callus in the wake of invasion by blood vessels, primordial marrow, spindle-shaped connective tissue cells, and osteoblasts.

The time sequence of these various processes was obscured by the overlap in the appearance of new structural changes. The hematoma was so large that organization of the core was incomplete at the time the periphery of granulation tissue was developing into fibrocartilaginous callus. Collars of new bone of considerable volume were already constructed around the main fragments. In a healing fracture between twenty and forty days, every phase of bone repair was visible. Differentiation and growth of new connective tissue was directed by diverse means to the development of bone across the fracture ends.

Eggers et al. (1949) used pressure to hold fracture ends together. They concluded that pressure in optimal amounts stimulated osteogenesis, while excessive pressure produced necrosis and non-union.

Ford et al. (1951) did some experiments with grafts and felt that pressure made little difference in the manner or rate of union.

Eggers et al. (1951) used slotted plates without the screws being drawn tightly to repair fractures clinically in man. This allowed the fractured ends to be under the same physical forces of contact and compression as are present in a closed reduction. Shaft fractures healed promptly with this plate. They felt that absorption and osteogenesis occurred concurrently, thus achieving a balance. They further stated that any method of fracture fixation which deprived the area

of the contact-compression factor (as they termed it) denied the parts of a useful and necessary physiological function.

Venable (1951) acknowledged the principle of attaining close approximation of the fracture ends to obtain uninterrupted bone union at the fracture site. Venable developed the first compression device which he termed an impactor. He further summarized that continuity of like cells with a blood supply uninterrupted by necrotic changes during healing facilitated tissue repair. Early engagement of like tissues was essential for prompt healing of all wounds. Closely maintained coaptation of fresh fracture ends was necessary for early healing of the injured bone without excess callus. He felt that callus was excessive bone scar formation due to instability and insufficient blood supply at the injured bone site during healing. Impacted coaptation secured total immobilization at the fracture site.

Friedenburg and French (1952) found that experimental fractures of the ulna of dogs healed faster when a compressing force of 12 to 18 pounds was used. Pressures of 30 pounds or greater caused necrosis of the cortex and poor healing.

They felt that enhanced healing under pressure was related more to secure fixation and impaction of the fracture. They were undecided whether pressure induced a specific osteogenic response in healing bone tissue. Key and Reynolds (1953) concurred with this idea. Their experiments showed that the most rapid and perfect fracture healing occurred when the

fragments were fused by appositional bone. They felt that clinicians should strive to create conditions under which the fusing by appositional bone could occur.

Ford and Key (1954) stated that pressure caused bone fragments to be immobilized and compressed together. They disagreed with Eggers in that they did not find that excessive pressure caused non-union.

Reynolds and Key (1954) compared standard bone plates, slotted plates, and intramedullary nails. They concluded that fixation and apposition of the fractured fragments were more important in obtaining union than the pressure created by weight bearing.

Bagby and Janes in 1958 devised their own compression plate. They used a plate in which the screws were placed off center in the hole. As the screws were tightened, this would create compression at the fracture site. In experimental studies using these plates on dog femurs, they concluded that compression reduced the fracture gap to a minimum and there-fore less time was needed to span the gap with callus. They felt that good immobilization favored early repair of a fracture. They believed that these factors allowed a fracture to heal by first intention. Little external callus was found in the fractures which united early.

Based on experiments done on the tibia of rabbits, Laurin et al. (1963) felt that compression dod not speed callus for-mation.

Muller (1963) stated that three months after the insertion of ordinary self-tapping screws in dogs, only connective tissue could be distinguished between the threads of the screws. He designed a screw with a thread which gave excellent holding power, but which had threads pre-cut in the bone with a tapping device. These screws were as well anchored in the bone after three months as on the first day. Only bone or newly formed bone could be detected between the threads.

Boyd et al. (1965) studied healing in the treatment of non-union fractures. They felt that the most important factors in successfully treating non-unions were firm fixation, apposition of the fragments, and osteogenesis. They believed that the best stimulus for osteogenesis was autogenous cancellous bone packed about the non-union.

Based on experimental work with fractures of dog femurs, Anderson (1965) agreed with preceding authors that reduction of space by compression reduced the healing time and increased the rigidity of fixation. He believed that plate and screw fixation did less damage to the medullary and cortical blood supply than other methods of internal fixation. He agreed with Muller in that he felt that using a sharp tap generated less heat which might cause necrosis of bone and loosening of the screw. He observed that the amount of callus decreased as the rigidity of fixation increased. Jacobs and Guten (1967) made similar observations when using compression plating in man.

In a paper on fracture healing in dogs and cats, Vaughn (1966) emphasized the role of callus in fracture healing. He observed that osteocytes are killed at the fracture site when a fracture occurs and that this death is due to an interruption of circulation in the Haversian vessels.

Wickstrom et al. (1967) evaluated the AO (which later became A.S.I.F.) compression apparatus. They agreed with several of the previous authors that compression promoted healing by enhancing immobility and producing close contact of bony surfaces. They did not observe bone necrosis at the compressed interface.

Putnam and Pennock (1969) used the A.S.I.F. compression equipment in both large and small animals. They observed that it was helpful to have immediate weight bearing after surgery. They reiterated that if fracture lines in the cortical bone are placed in close apposition, osteogenesis can occur directly from each fragment of cortex across the fracture line.

Naiman et al. (1970) used A.S.I.F. plates on upper extremity fractures in man. The improved rigidity allowed earlier union limiting the period of external immobility and permitted earlier rehabilitative therapy. They reported a high incidence of excellent functional results.

Hickcox (1970) used a Richards plate in dogs, that was slotted, which allowed compression from the center (Hirschhorn modification) and decreased the required area of exposure.

He was impressed with the rapid ambulation and near absence of post-operative pain.

Herron and Doonan (1971) reported excellent results in using A.S.I.F. compression plating in non-union fractures in dogs.

Horne (1971) reiterated the advantages of plating as stated by previous authors. He also found that the Hirschhorn plate required less exposure than other methods of compression. He observed that the Richards screw had a fluted end which removed chips and this prevented clogging of the threads and binding of the screw. It also had buttress threads, which increased holding power and eliminated back pressure.

Burwell (1971) used plating for tibial fractures in man. He observed that these patients had less joint stiffness, absence of deformity, and more certain union of the fracture without need for prolonged immobilization.

Wolff (1972) and Muller et al. (1970) stated that in fracture repair it was necessary to get as accurate an anatomic reduction as possible and rigid internal fixation of fragments during the entire period of fracture healing. This permitted primary bone union - union without any radiologically visible periosteal callus.

Uhthoff and Dubuc (1971) observed some disadvantages in the healing of fractures repaired with plates. In a study on dog femurs, they showed that reduction in shaft caliber and cancellization of the cortices occurred from the bypassing

effect of the plate. In their work, the cortical bone was transformed into cancellous bone and replaced by an incompletely mineralized woven bone. They also noted some subperiosteal bone resorption.

In 1971 Zaslow and Lenhard reported success in using compression plates for immobilization of foreleg fractures in the dog. They noted quick restoration of weight bearing and good anatomical reduction in this use of compression plates.

Bone plates have been used in areas other than limb fractures. Sumner-Smith and Dingwall (1971) used plates in repairing fractures of the mandible in dogs. In six cases, they noted that the dogs could eat immediately after surgery, had less pain, and had rapid healing with less callus formation.

MATERIALS AND METHODS

Experimental Animals

Twelve dogs were used in this study. The dogs were of mixed breeding and were selected without regard to age or sex. All dogs weighed 10 Kg or more. Each dog was given a physical examination to insure that it was in good health and that no lameness existed. All dogs were vaccinated for canine distemper, hepatitis, and leptospirosis and were treated for internal and external parasites when found.

The dogs were kenneled in steel cages and were allowed to exercise for about 20 minutes twice daily. Cages were cleaned at least twice daily and disinfected once each day. Water and commercial dry dog food were given free choice. The twelve dogs were divided into 3 groups of four dogs each. Following surgical implantation of the bone plates, each dog was observed and evaluated for a variable length of time. Group 1 was observed for 8 weeks, Group 2 for 16 weeks, and Group 3 was observed for 40 weeks postoperatively. Clinically, the dogs were observed for return of weight bearing and freedom from limping.

At the end of the observation period the dogs were euthanized with a concentrated pentobarbital sodium solution.[1] Necropsies were performed and both femurs were removed in their

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[1]Toxital, Jensen-Salsbury Laboratories, Kansas City, Missouri.

entirety. Each femur was manipulated to evaluate gross stability with the plate in place. The muscle tissue was then stripped from the bone, the screws removed and the plate taken off. The bone, screws and plate were observed for discoloration, and the tissue observed for reactivity to the plate or screws. Stability of the fracture site (without plate) was evaluated by applying moderate manual pressure (Figs. 1A, B, C).

The femoral head, neck, and greater trochanter were removed from each femur by making a cut with a band saw at a 90 degree angle to the long axis of the femur. The condylar area of the femur was removed by making a cut at a 45 degree angle to the long axis of the femur. Cutting at different angles helped to identify the proximal and distal ends of the segment. All of the screw holes were included in the portion of femur which was saved (Fig. 1D). The bones were split longitudinally in an anterio-posterior plane with a band saw (Fig. 1E).

The femurs were radiographed by laying the split portions of each femur side by side with both femurs from one dog on the same cassette. The right femur was marked with an R and the left femur with an L. Each dog's identification number was included on the radiograph. All femurs were radiographed at 50 KVP, 100 MA, 1/20 second, and at a 30 inch distance (Fig. 2).

The femurs were placed in 10% buffered formalin for at least 72 hours. The bone specimens were then cut (Fig. 3) and decalcified in a 10% solution of ethylene dinitrilo
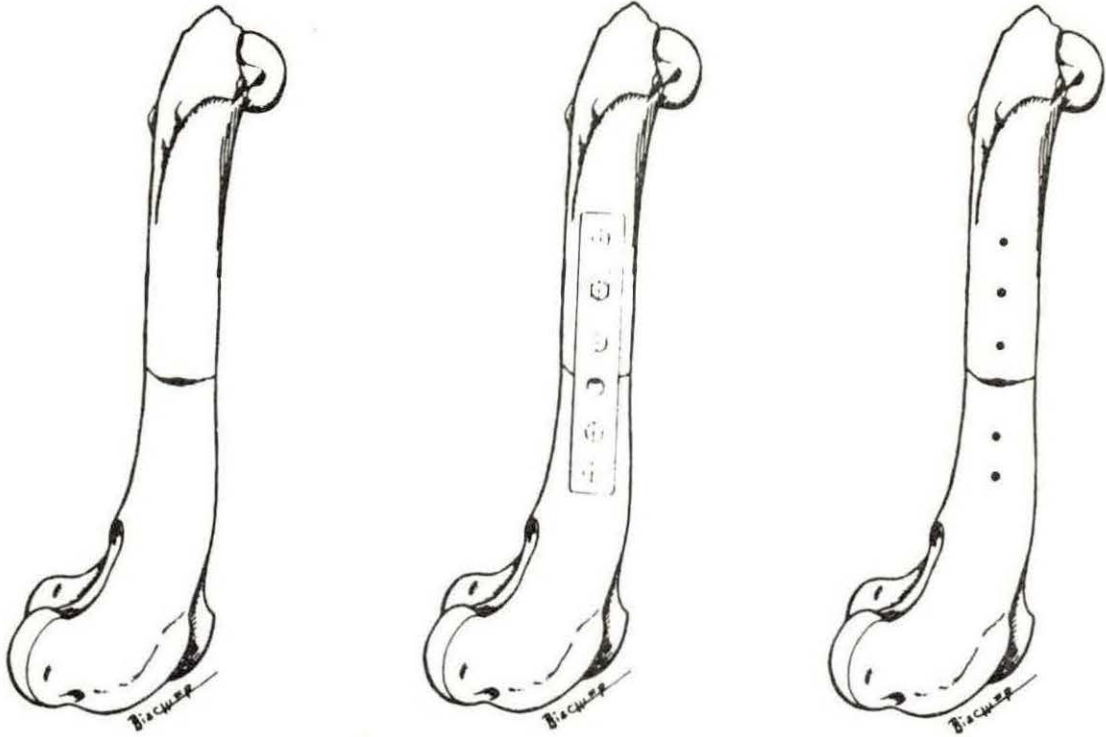
Fig. 1A.   A femur with a transverse mid-shaft fracture

Fig. 1B.   The fracture has been reduced and a compression
            plate applied.

Fig. 1C.   Healing has taken place and the plate has been
            removed.
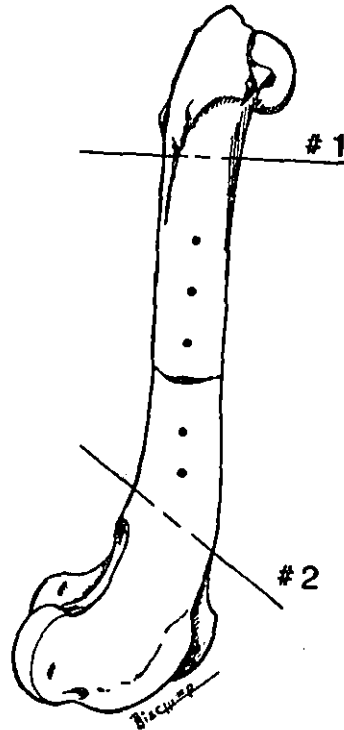
Fig. 1D. The femoral head and greater trochanter were removed with a transverse cut (— — — #1). The condyles were removed with an oblique cut (— — — #2).
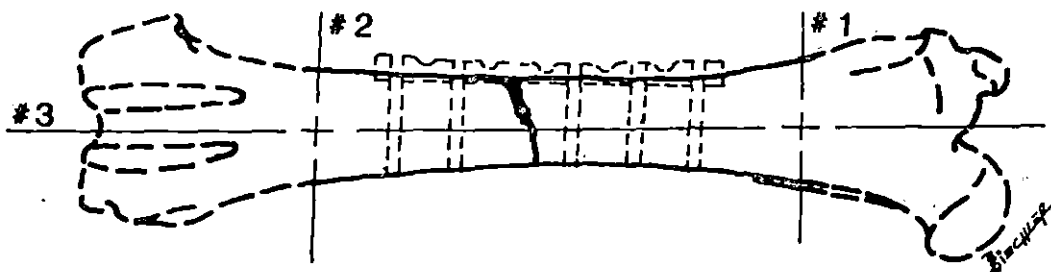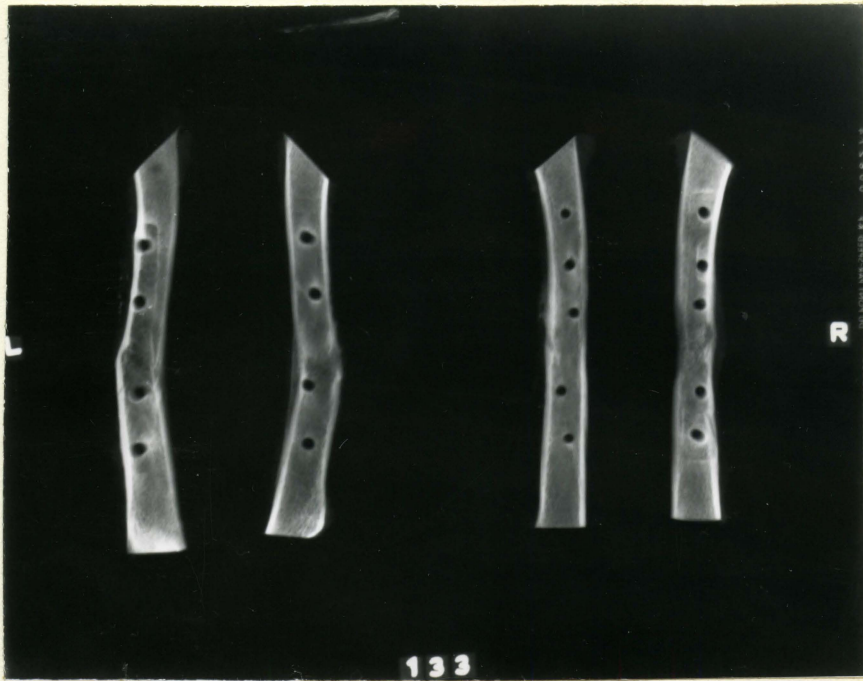

Fig. 1E. The femurs were split longitudinally (cut #3).

Fig. 2.   Radiograph of split portions of both femurs of dog 133

Fig. 3.   Cut #4 was made through the proximal screwhole. A
          microscopic section was taken from that face.

          Cuts #5 and #6 were made through the holes adjacent
          to the fracture site.

          Cut #7 divided that section longitudinally through
          the screw holes. A microscopic section was taken
          from that face.

1

1

4

5

6

7

2

BIECHLER # 2
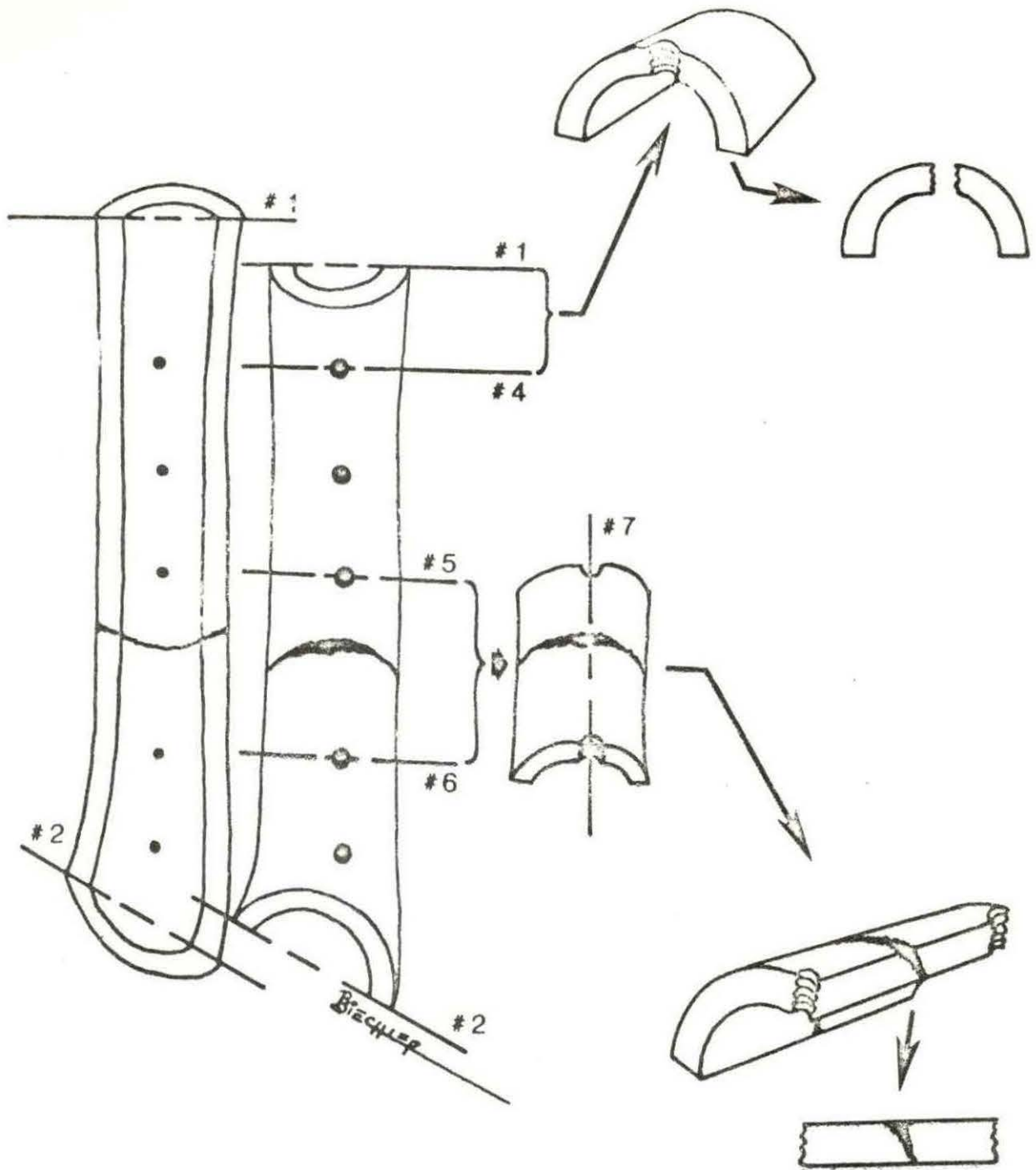
tetraacetic acid disodium salt[1] for at least 21 days. Fresh EDTA solution was added after the 10th day. The decalcified bone tissues were embedded in paraffin and the cut sections stained with hematoxylin and eosin.

Anesthesia and Presurgical Preparation

Each dog was administered intravenously .07 mg/Kg body weight of atropine sulfate in combination with 5% thiamylal sodium[2]. The thiamylal sodium was given to effect for the purpose of endotracheal intubation. General anesthesia was maintained with methoxyflurane[3] in a semi-closed circle system.

For all practical purposes, the hair from the rear half of each dog was clipped. Hair was clipped from the last rib caudally; down each rear leg to the hock joint on all aspects, and hair was clipped a short way down the tail. The surgical field was scrubbed at least three times with povidone-iodine[4] surgical soap and rinsed each time with alcohol. Just prior to surgery, a final application of povidone-iodine solution was applied with a hand sprayer.

In the surgery room the patient was positioned in lateral

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[1]EDTA disodium salt, Matheson, Coleman, and Bell Manufacturing Chemists, Norwood, Ohio.

[2]Surital, Parke-Davis and Company, Detroit, Michigan.

[3]Metofane, Pitman-Moore, Indianapolis, Indiana.

[4]Betadine, The Purdue Frederick Company, Norwalk, Connecticut.

recumbency with the rear limb to be operated on suspended from an IV stand with gauze (Fig. 4). The surgeon scrubbed with povidone-iodine surgical soap and then donned a sterile surgical gown and surgical gloves. Four towels were draped at right angles surrounding the thigh (Fig. 5). The limb was freed from the IV stand by an assistant and held while a sterile 4" orthopedic stockinette was started onto the foot by the surgeon (Fig. 6). The surgeon would then grasp the foot through the stockinette and roll the stockinette up the leg and secure it with towel clamps. An aperture was cut in a sterile disposable drape and the limb placed through the opening (Fig. 7). The remainder of the patient and the surgical table were covered with sterile drapes.

Surgical Technique

The Richards equipment was used on the right leg and the A.S.I.F. equipment on the left. The leg to be operated on first was selected at random.

A lateral approach was used to expose the femur. A skin incision was made from the greater trochanter to the patella (Fig. 8). The incision was continued down through the subcutaneous fascia. The junction of the biceps femoris muscle and the fascia lata was incised along the entire length of the skin incision (Fig. 9). The biceps muscle was retracted caudally and the vastus lateralis muscle cranially to expose the shaft of the femur (Fig. 10).

Fig. 4. Rear limb to be operated on was suspended from an
         IV stand with gauze

Fig. 5.   Four towels were draped at right angles surrounding
          the thigh

Fig. 6. Limb was held by an assistant while a stockinette
         was started on the foot

Fig. 7. Draping has been completed with disposable drapes

Fig. 8.   Skin incision has been made from the greater
          trochanter to the patella
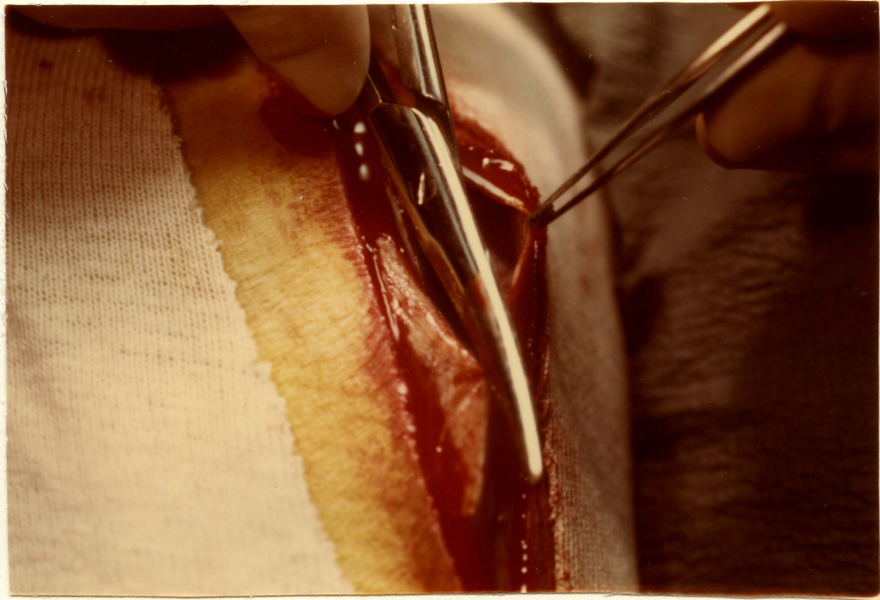
Fig. 9. Junction of the biceps femoris muscle and the fascia
          lata was incised along the length of the skin incision

Fig. 10. Biceps muscle was retracted caudally and the vastus
          lateralis muscle cranially to expose the shaft of
          the femur

A transverse mid-shaft fracture of the femur was created
with the use of a guillotine-type bone breaker designed by
the author (Fig. 11). The breaker was positioned on the femur
so that the fork of the breaker was on the anterior-medial
surface of the femur and the movable blade was on the posterior-
lateral aspect of the femur (Fig. 12). The handle was turned
clockwise until the bone broke. Pressure was then released,
the breaker was removed, and any periosteum which had remained
intact was broken down manually. Invariably, a single trans-
verse fracture resulted (Fig. 13).

Right femur (Richards equipment)

A Richards bone plate of the proper length was selected
(Fig. 14). The length of the femur and the amount of exposure
influenced the choice of plate length. A rule of thumb was to
use a plate five times as long as the diameter of the bone.
The decision as to whether the slotted portion of the plate
should be placed on the proximal or distal fragment was
determined by the exposure. Generally, the slotted portion
was placed on the fragment where exposure was the greatest.
The non-slotted end of the plate was held to the bone fragment
with a Richards bone holding forcep (Fig. 15). The second hole
from the non-slotted end was drilled with a hand drill using
a 7/64" drill bit. Centering the drill bit in the hole in the
plate was facilitated by using a drill guide (Fig. 16).

A depth gauge was used to determine the proper length
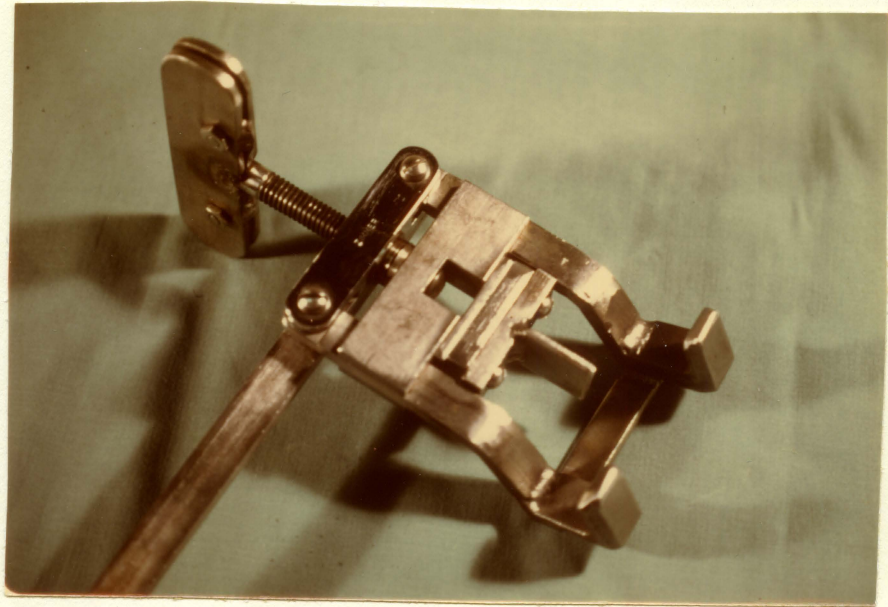
Fig. 11. Guillotine-type bone breaker
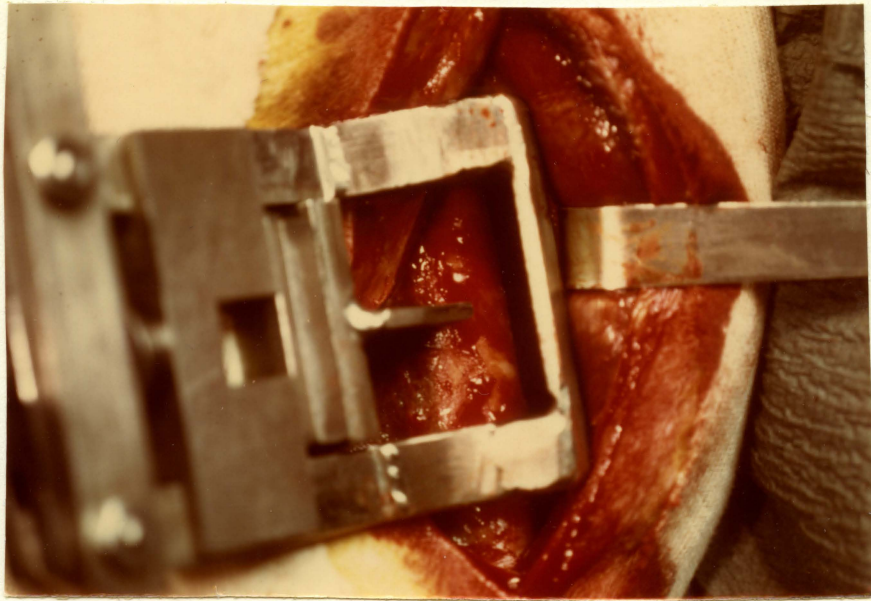
Fig. 12. Bone breaker has been placed on the femur

Fig. 13. Transverse mid-shaft fracture has been created
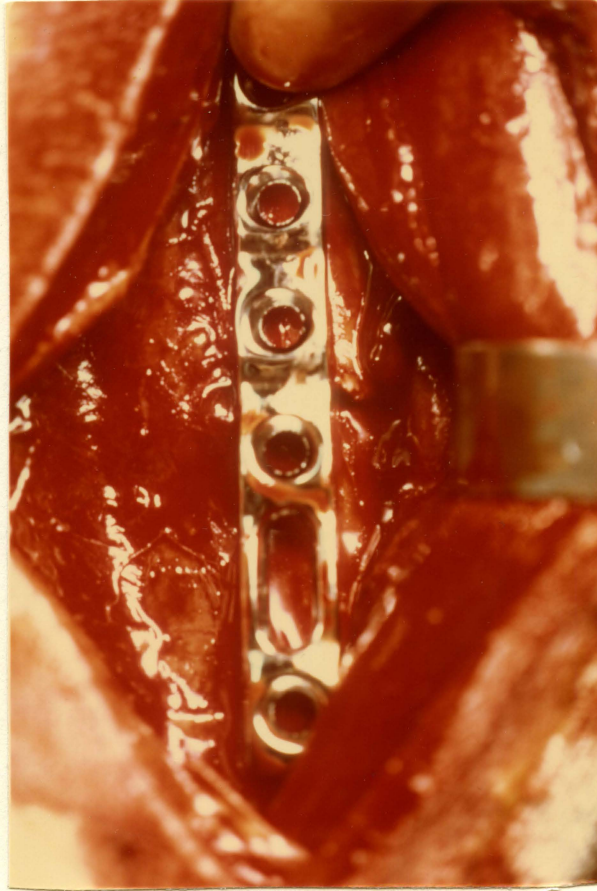
Fig. 14. A proper length Richards plate has been selected
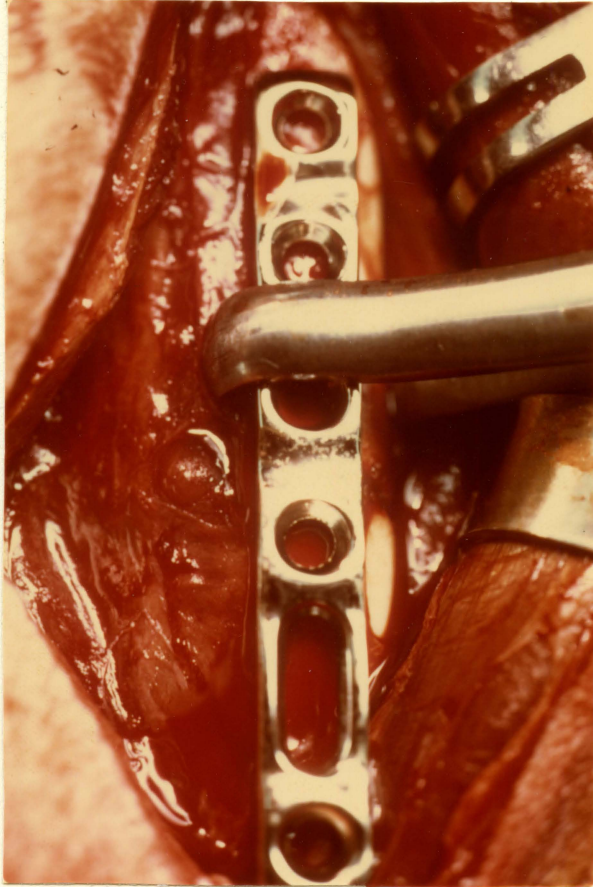
Fig. 15. The non-slotted end of the plate was held to the
          proximal fragment with a Richards bone holding
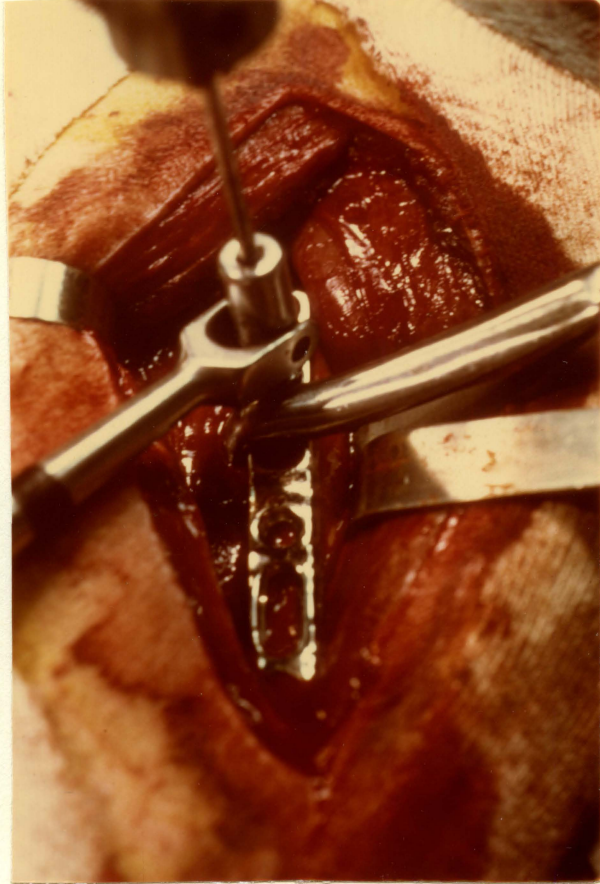   forcep

Fig. 16.   A drill guide was used to center the drill bit for drilling the bone at the second hole from the end

screw to use (Fig. 17). The ideal length of screw penetrated the opposite cortex by about one full thread. The appropriate length self-tapping screw was placed in the hole and tightened until snug, but not tight (Fig. 18). The fracture ends were brought into alignment and held in position by placing a baby Kern bone holding forceps over the plate and around the medial side of the fracture segment at the slotted end of the plate. The compression device was set in position and used as a guide for drilling the hole for the screw used to anchor the compression device (Fig. 19). The screw placed through the compression device was longer than the other bone screws since it had to go through the compression device and both cortices (Fig. 20). A compression wrench was used to tighten the compression device until some resistance was felt (Fig. 21). At this point, the plate was snug and well aligned along the *long* axis of the bone. The bone was then drilled at the end hole at the non-slotted end of the plate and a screw of appropriate length was placed (Figs. 22 and 23).

The compression device was then further tightened until it turned with difficulty. Visually the fracture was well compressed (Fig. 24). Another hole was drilled, this time at the end hole of the slotted end of the plate (Fig. 25). A screw of proper length was placed (Fig. 26). The compression device was loosened with the compression wrench and the compression device removed by removing the extra long bone
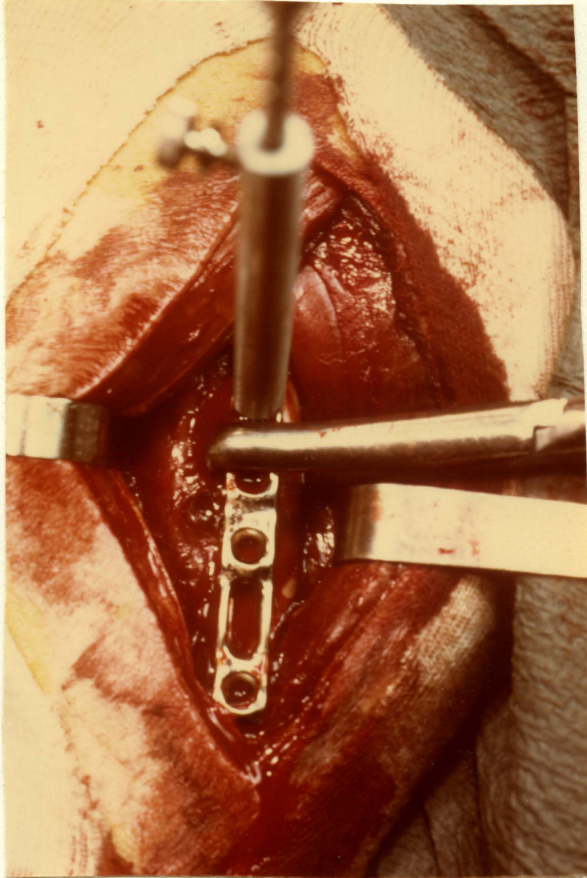
Fig. 17. Depth gauge was used to determine the proper length
          screw to use
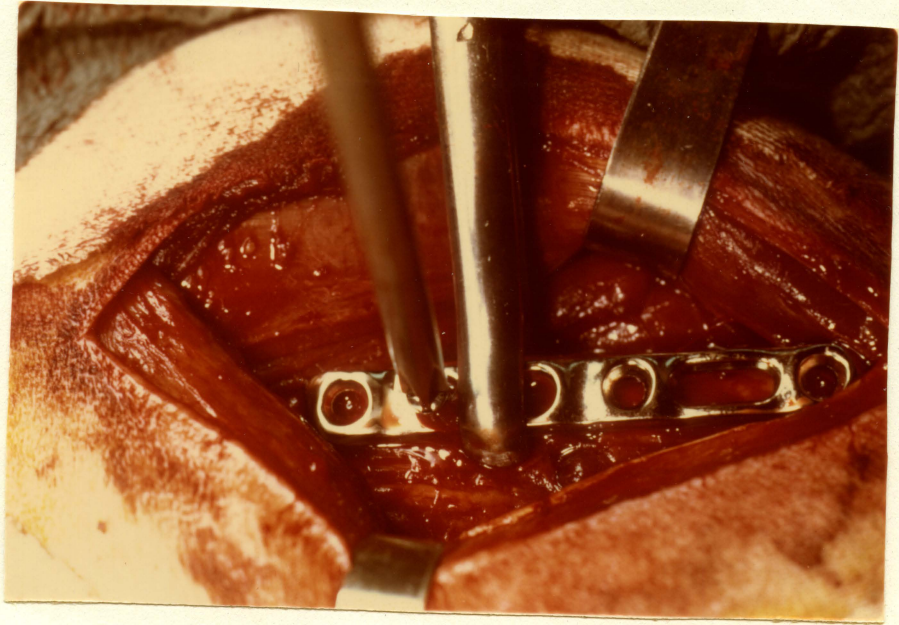
Fig. 18. A screw was placed in that hole
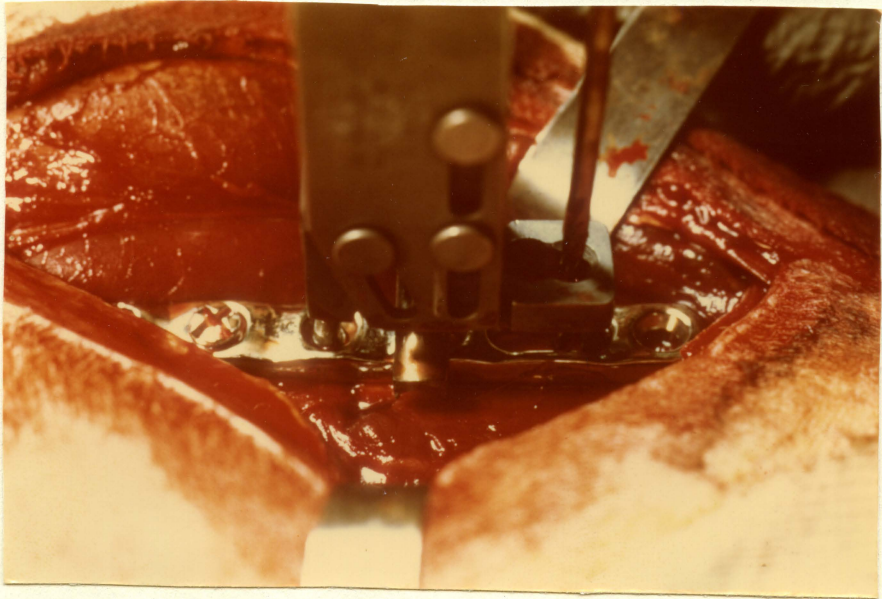
Fig. 19.   Compression device was set in position and used as
          a guide for drilling the hole for the screw to
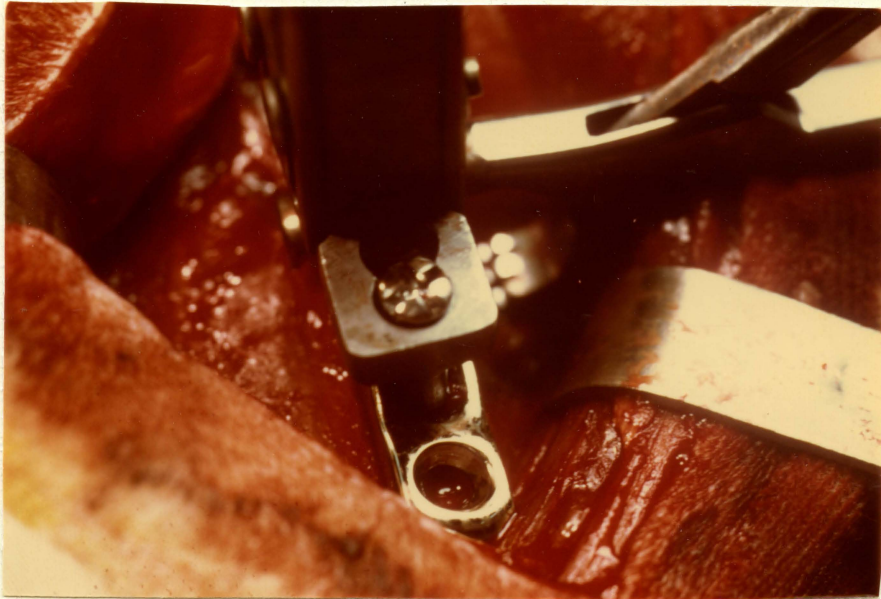   anchor the compression device

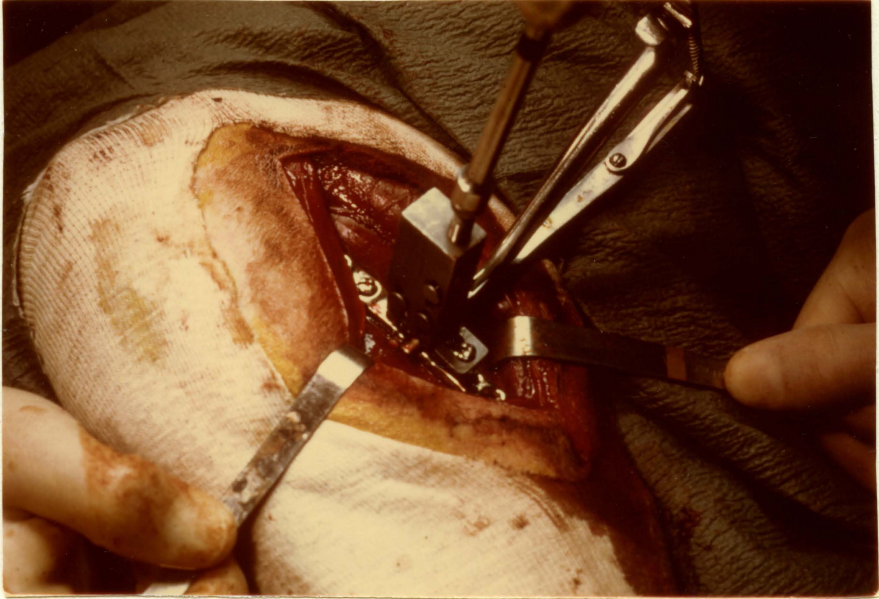Fig. 20. A screw was placed to anchor the compression device

Fig. 21. A compression wrench was used to tighten the com-
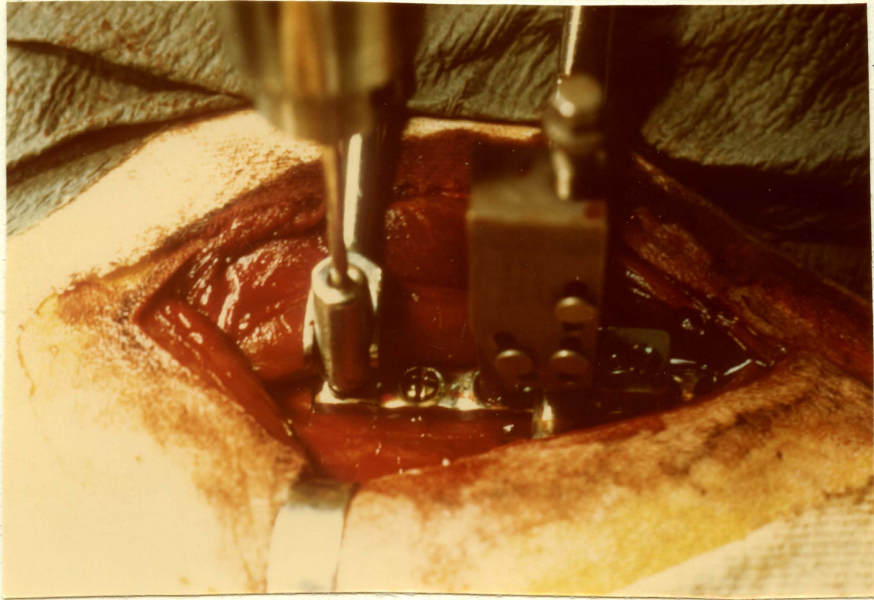   pression device until some resistance was felt

Fig. 22.   A hole was then drilled at the non-slotted end of
           the plate
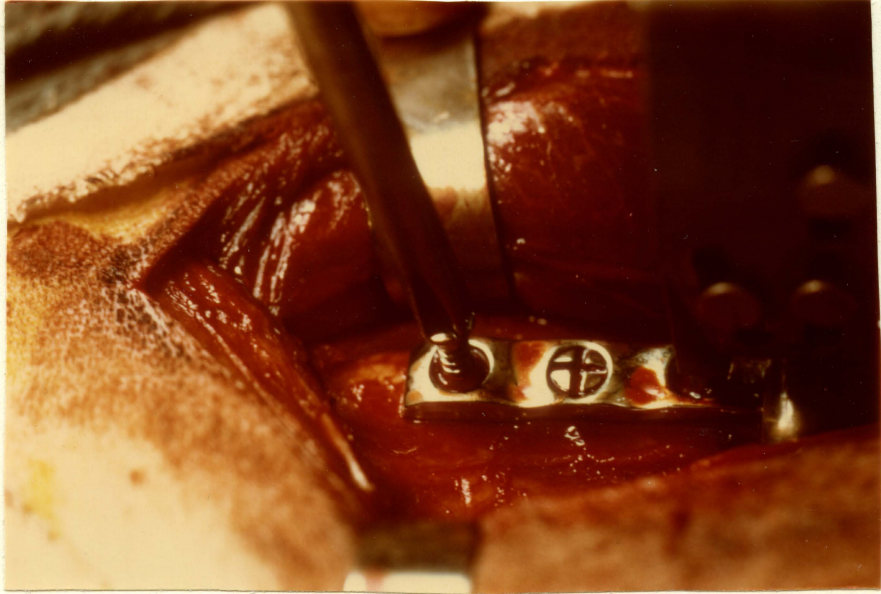
Fig. 23.   A screw of the appropriate length was placed in the
           end hole
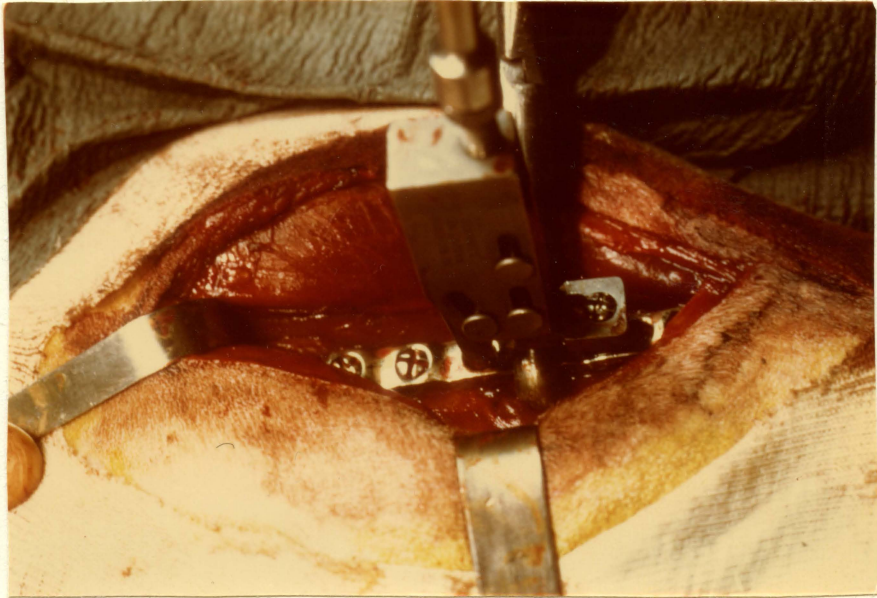
Fig. 24.   The compression device was further tightened until
the fracture was well compressed
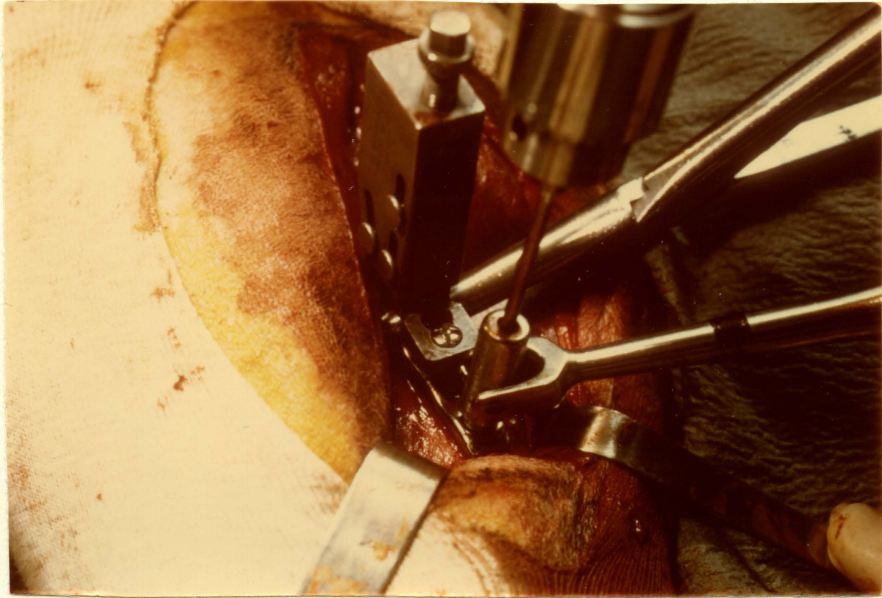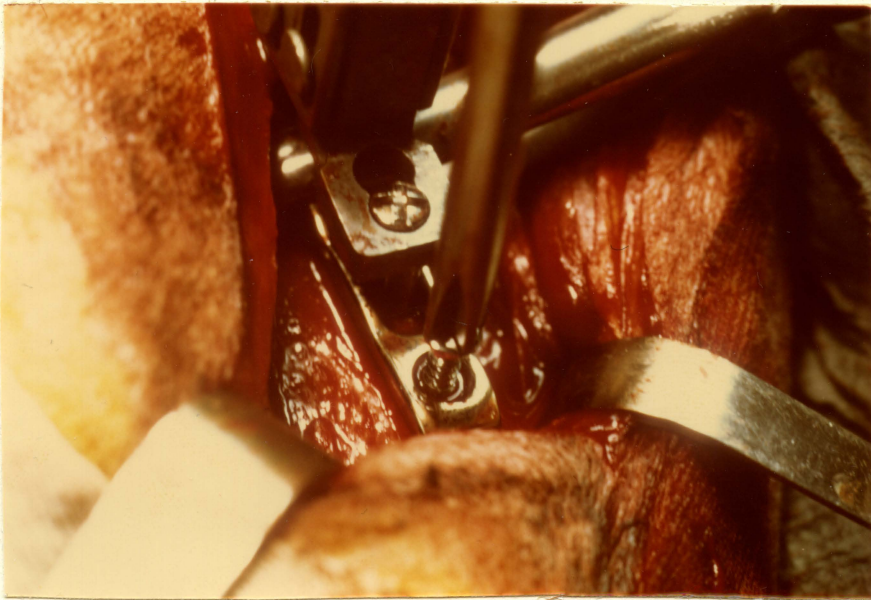
Fig. 25. A hole was drilled at the slotted end of the plate

Fig. 26.   A screw was placed in the end hole

screw. A shorter length bone screw was placed in this hole
(Fig. 27). Holes were drilled in the bone at the remaining
holes in the plate and appropriate screws were inserted except
where the hole and screw would pass through the fracture line
(Fig. 28). In all cases there were at least two screws on each
side of the fracture line.

The biceps muscle was reattached to the fascia lata with
simple interrupted sutures of 0 chromic surgical gut (Fig. 29).
The subcutaneous tissue was closed with simple interrupted
sutures of 00 chromic surgical gut. The sutures were placed
in an inverted manner so as to bury the knots in the deeper
tissues (Fig. 30). Simple interrupted sutures of 32 gauge
monofilament stainless steel wire were used to close the skin
incision (Fig. 31).

An assistant then positioned the dog in right lateral
recumbency. The left leg was suspended with gauze from an
IV stand and prepped as the right leg had been. The surgeon
changed gloves and instruments. Sterile draping was performed
for the left leg as previously described for the right leg.

Left femur (A.S.I.F.)

Exposure of the left femur was similar to that of the
right, and the fracture was produced in the same manner
(Fig. 32). An A.S.I.F. plate of the proper length was
selected (Fig. 33). After the fracture had been reduced the
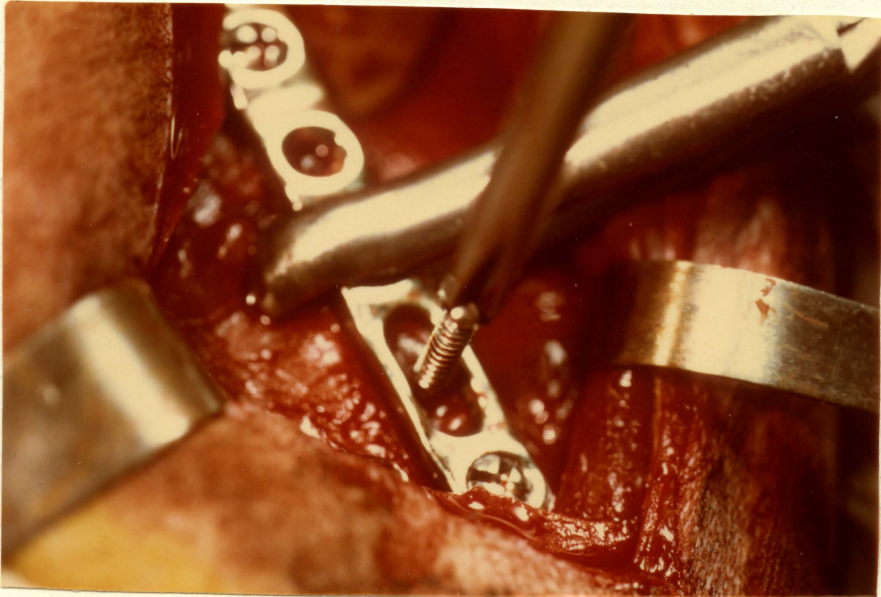plate was positioned on the lateral aspect of the femur. The

Fig. 27. The compression device was removed and a proper
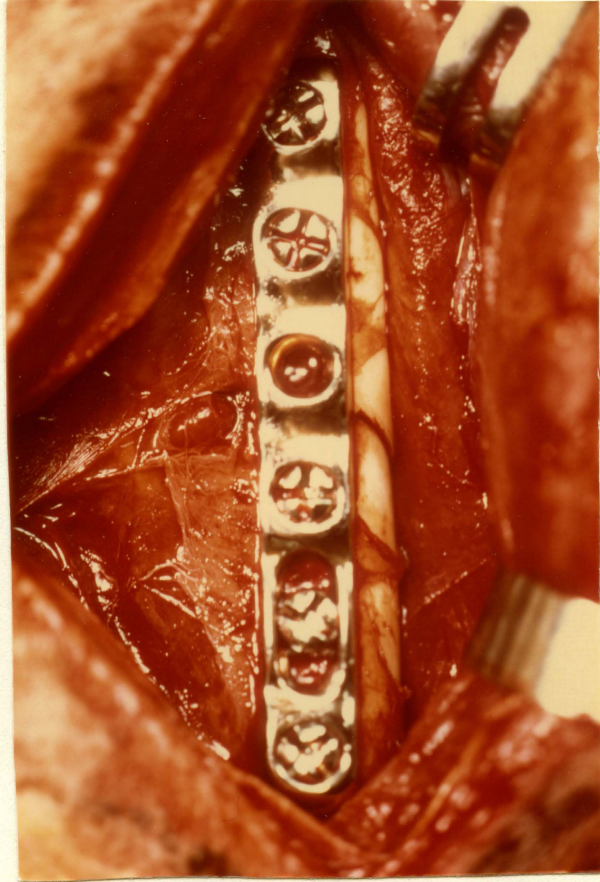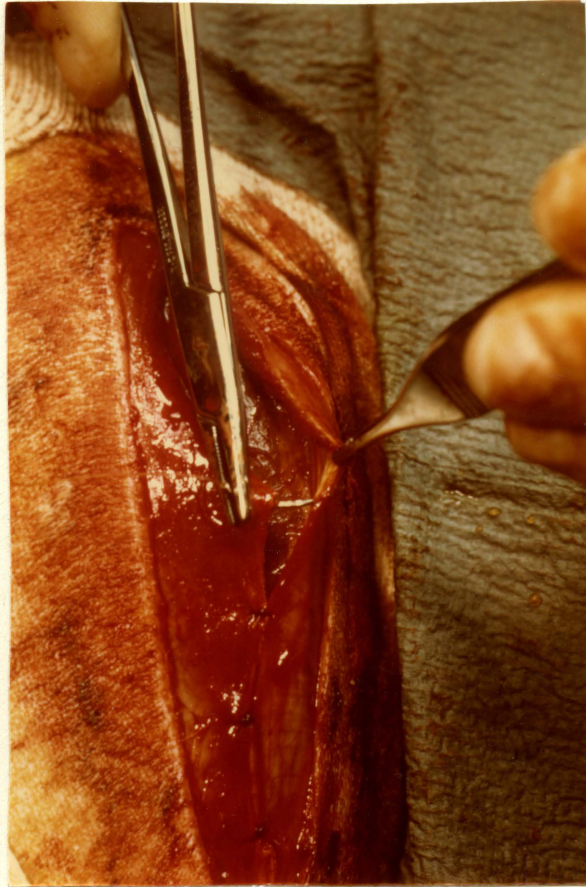length screw placed in the slotted hole

Fig. 28. The completed plating

Fig. 29. The biceps muscle was reattached to the fascia lata
          with simple interrupted sutures of O chromic surgi-
          cal gut

Fig. 30. The subcutaneous tissues were closed with simple
          interrupted sutures of 00 chromic surgical gut in
          an inverted manner

Fig. 31. The skin was closed with simple interrupted suture
of 32 gauge monofilament stainless steel wire
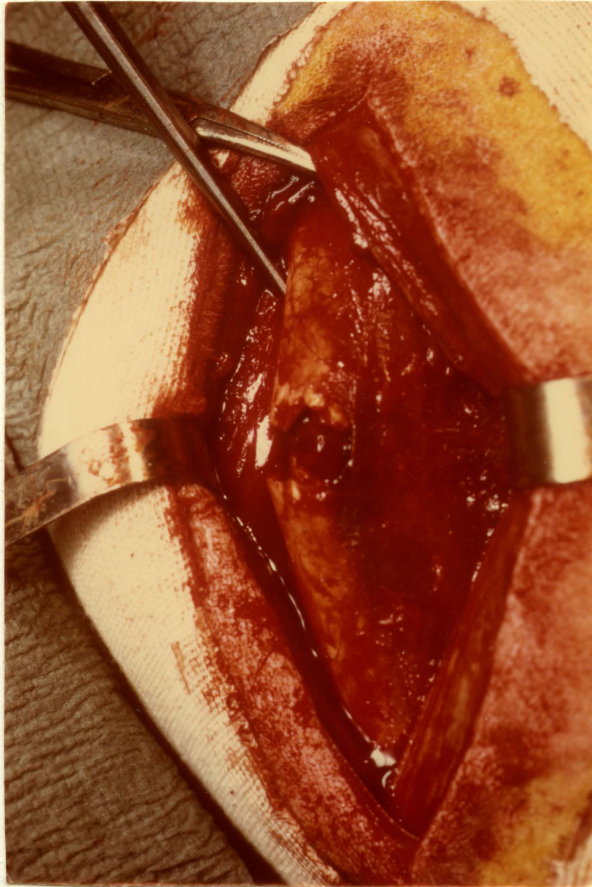
Fig. 32.   A transverse mid-shaft fracture of the left femur
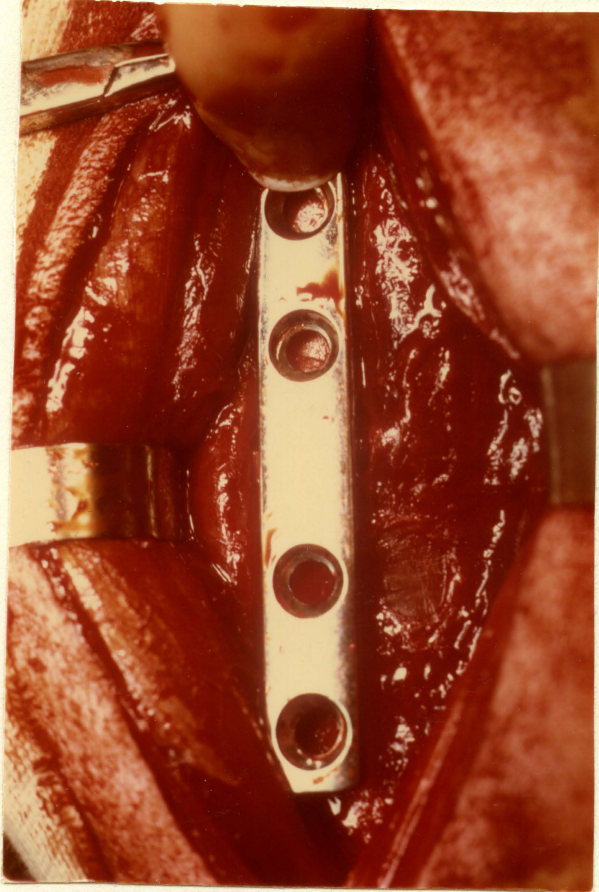   was created

Fig. 33. An A.S.I.F. plate of the proper length was selected

to be positioned to allow the compression device to be placed
at one end of the plate. This required additional exposure
since the compression device projected about 3 cm beyond the
end of the plate. The end of the plate opposite that to be
used for compression was held to the bone with Verbrugge bone
holding forceps (Fig. 34). The second to the end hole at the
end of the plate held by the bone forceps was drilled with a
3.2 mm drill bit. A drill guide was again used to center the
hole in the plate with the hole being drilled in the bone
(Fig. 35). Similarly a depth gauge was inserted and used to
find the correct length of screw required (Figs. 36 and 37).
Contrary to the Richards system, a bone tap was used to cut
threads in both cortices of the bone. This procedure was
necessary since an A.S.I.F. screw has no cutting edge (Fig. 38).
A screw scale was used to find a screw of the proper length
(Fig. 39). A screw of the proper length was inserted and
tightened until it was snug (Fig. 40). The fracture ends
were aligned and held in position with Vergrugge forceps
placed over the end of the plate and the bone fragment not
yet attached to the plate.

The guide for establishing the distance from the end of
the plate for the hole for the screw to anchor the compression
device was positioned (Fig. 41). The anchor hole was drilled
and the threads tapped (Figs. 42 and 43). The compression
device was set into position and the anchor screw was placed
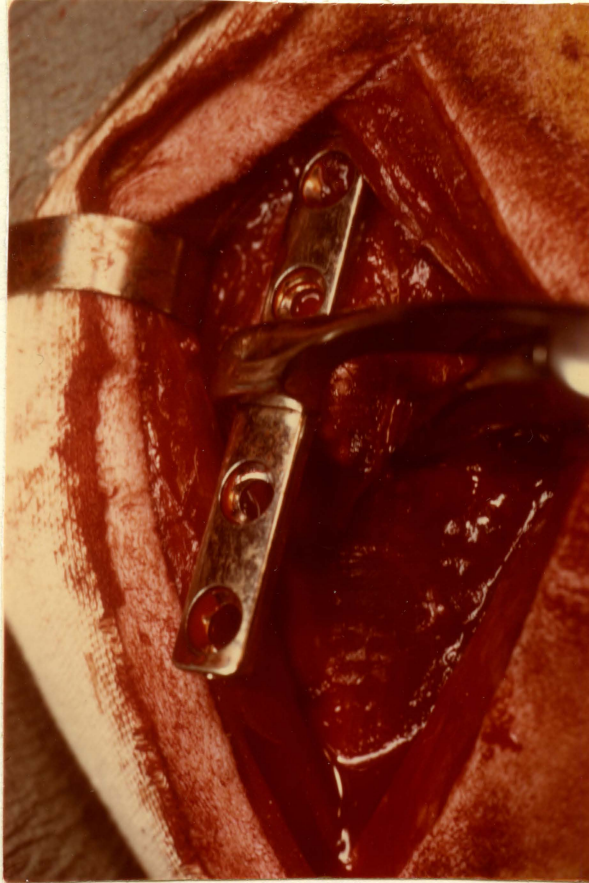(Fig. 44). The compression wrench was used to tighten the

Fig. 34.   The plate was held to the proximal fragment with
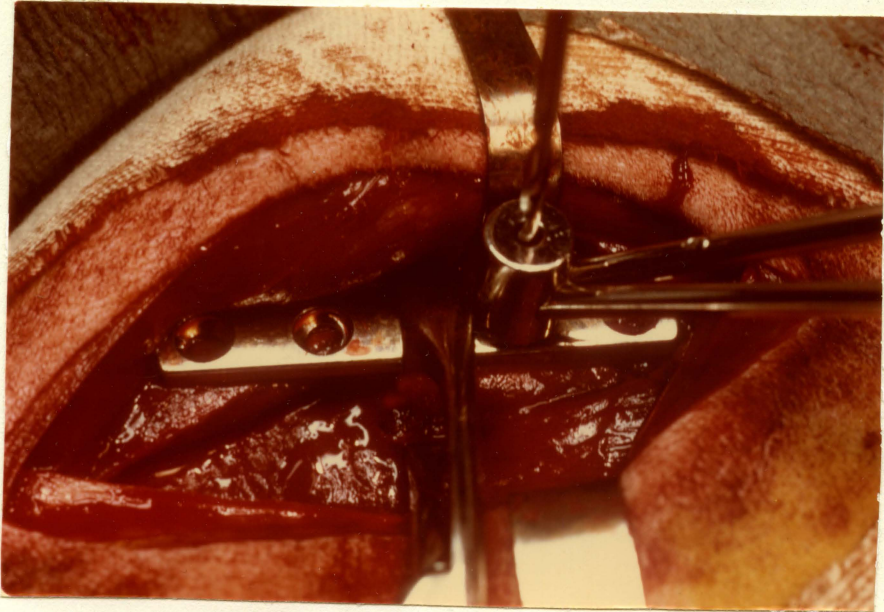   Verbrugge bone holding forceps

Fig. 35. A drill guide was used to center the drill bit for
          drilling the second hole from the end of the plate
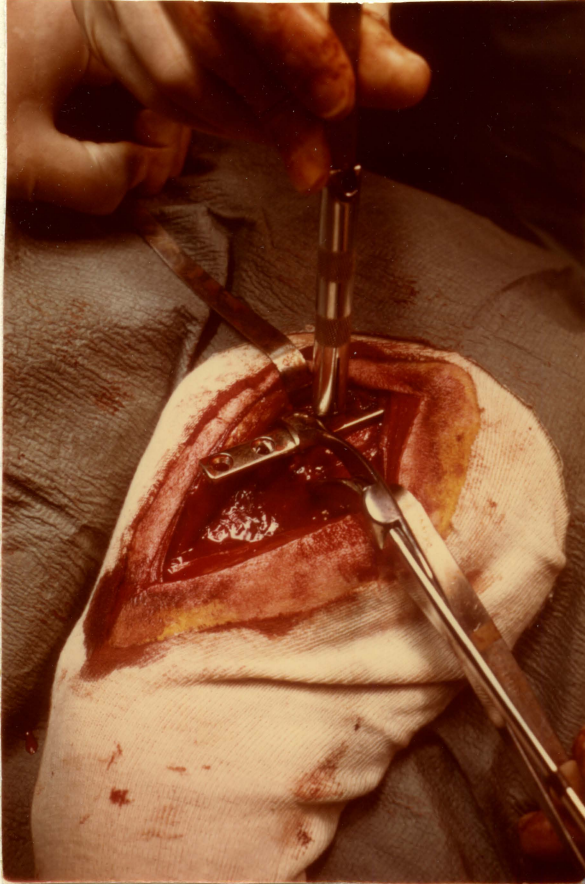
Fig. 36. A depth gauge was used to determine the length of
        screw required

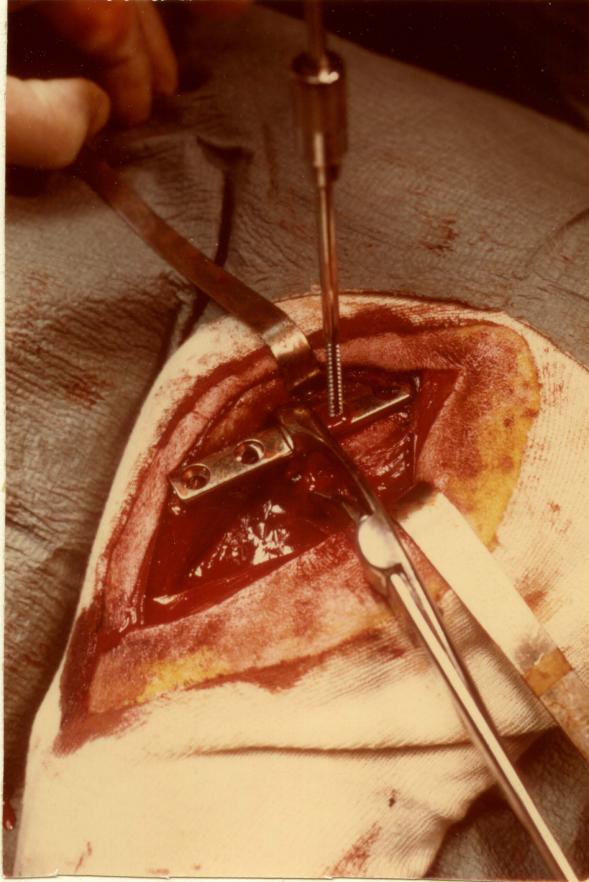Fig. 37.   The screw length required was read off the depth
            gauge

Fig. 38. A tap was used to cut threads in the bone

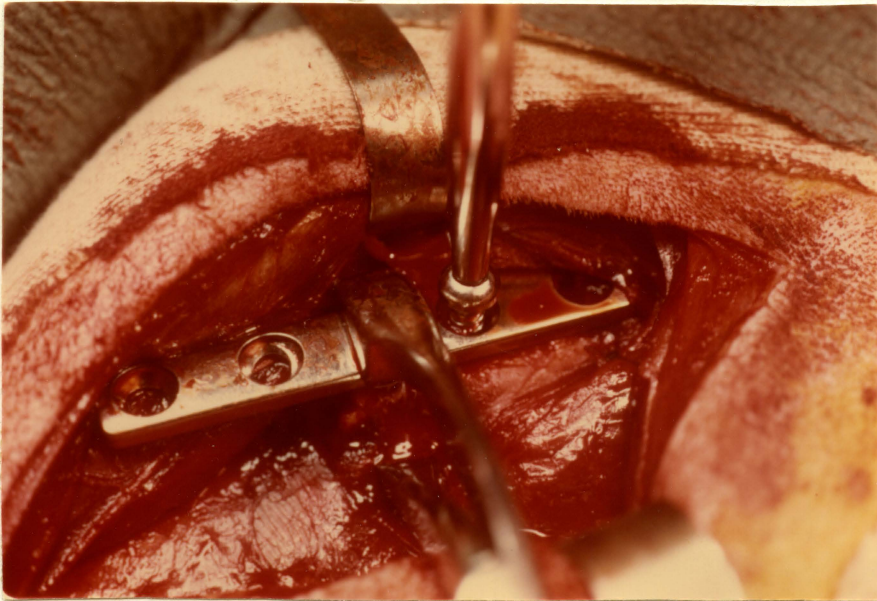Fig. 39.   A screw scale was used to measure the screw

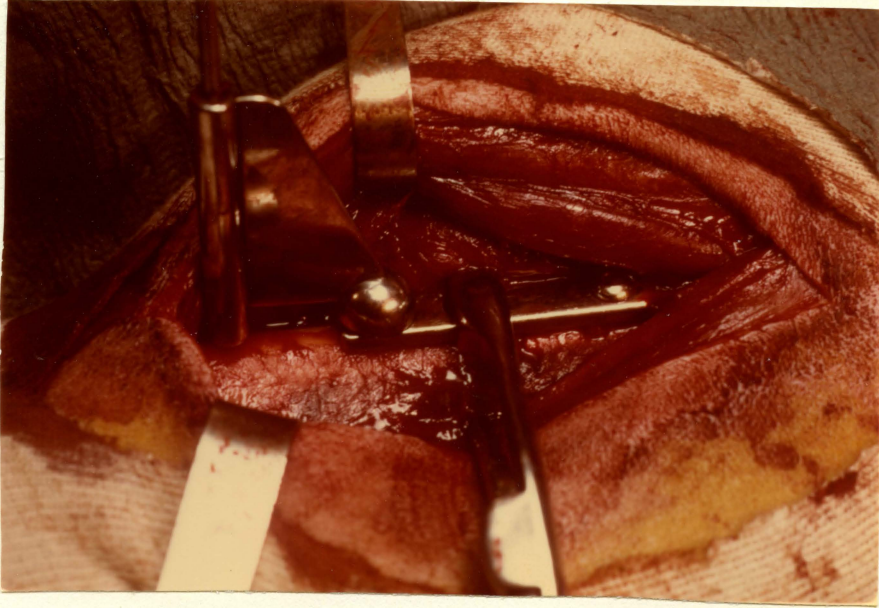Fig. 40. The screw was inserted and tightened until snug

Fig. 41. A guide for establishing the distance from the end
of the plate for the hole for the anchor screw for
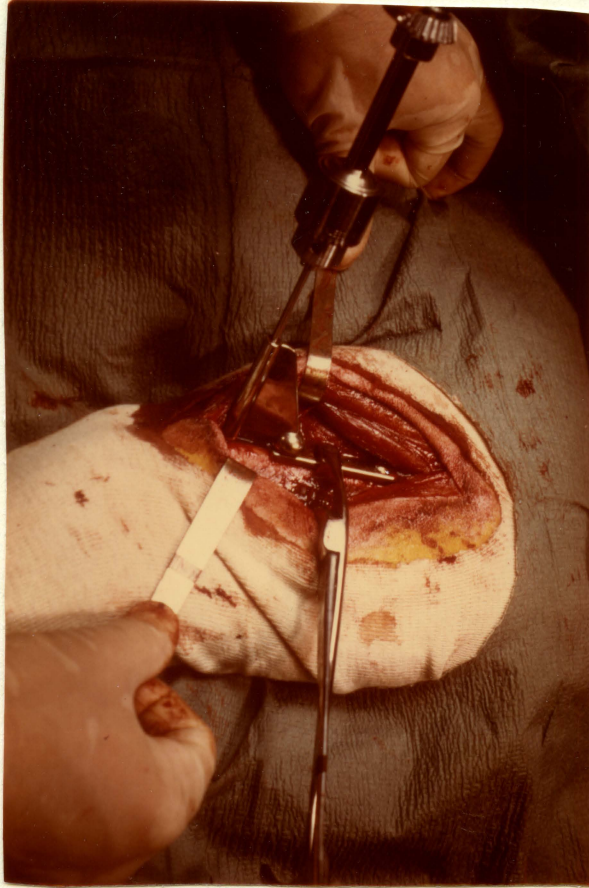the compression device was positioned

Fig. 42.   Using the guide the anchor hole was drilled
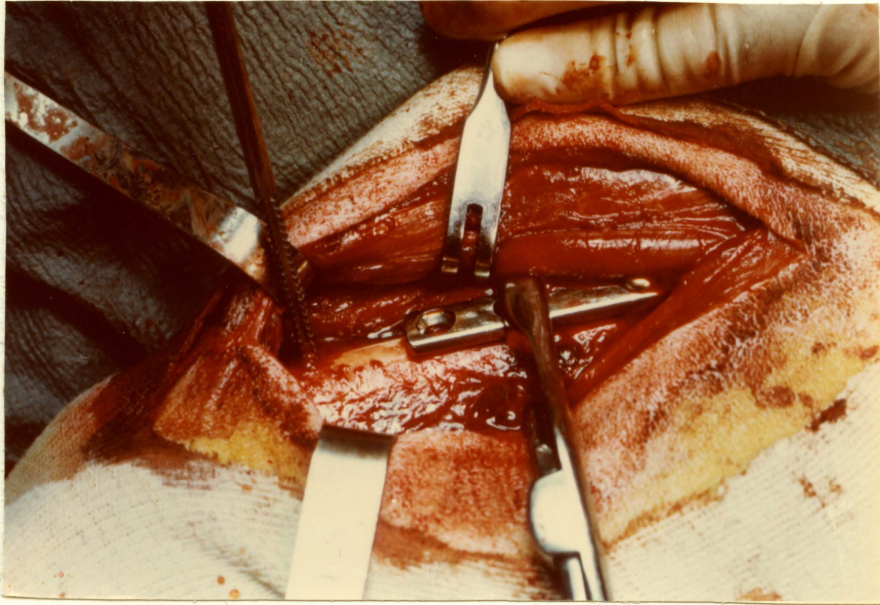
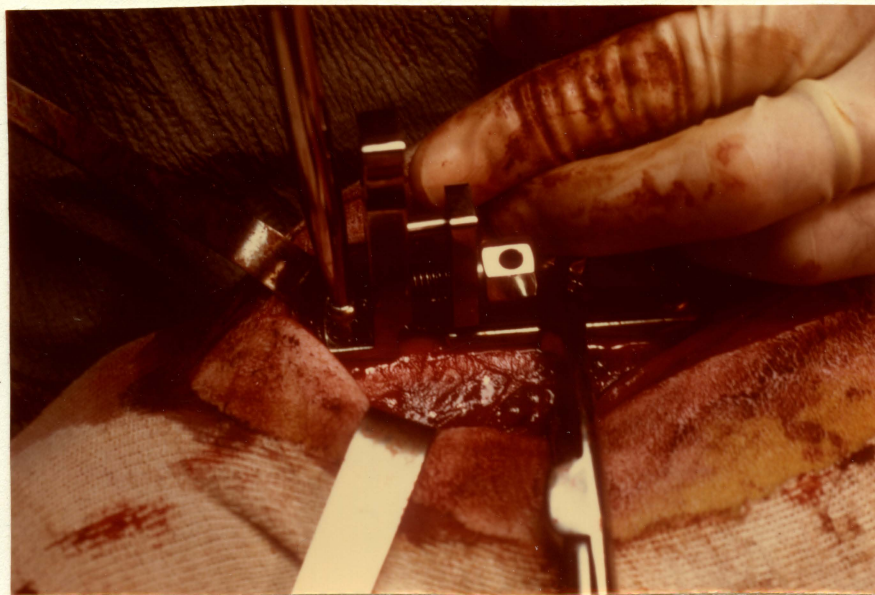Fig. 43. The threads were tapped for the anchor hole

Fig. 44. The compression device was positioned and anchor
          screw placed

compression device until some resistance was felt (Fig. 45). At this point, the plate was fairly well aligned along the long axis of the bone. A hole was then drilled at the end hole of the plate opposite the end with the compression device (Fig. 46). The depth of the hole was measured, the threads tapped, and the proper length screw inserted and tightened (Fig. 47). The compression device was turned until much resistance was experienced. Visually the fracture was well compressed (Fig. 48).

A hole was drilled in the bone at the hole in the plate adjacent to the compression device (Fig. 49). Length was measured, threads tapped, and the appropriate screw placed in the hole (Fig. 50). Holes were then drilled, tapped, and screws placed under any remaining holes in the plate. Holes were not drilled where the screw might pass through the fracture line.

The compression device was then removed. A hole was drilled in bone at the hole in the plate where the compression device had been. The threads were tapped and a screw of the appropriate length was used to complete the plating (Fig. 51).

The biceps muscle was reattached to the fascia lata with simple interrupted sutures of 0 chromic surgical gut. The subcutaneous tissues were closed with simple interrupted inverted sutures of 00 chromic surgical gut. The skin was closed with simple interrupted sutures of 32 gauge stainless steel wire.
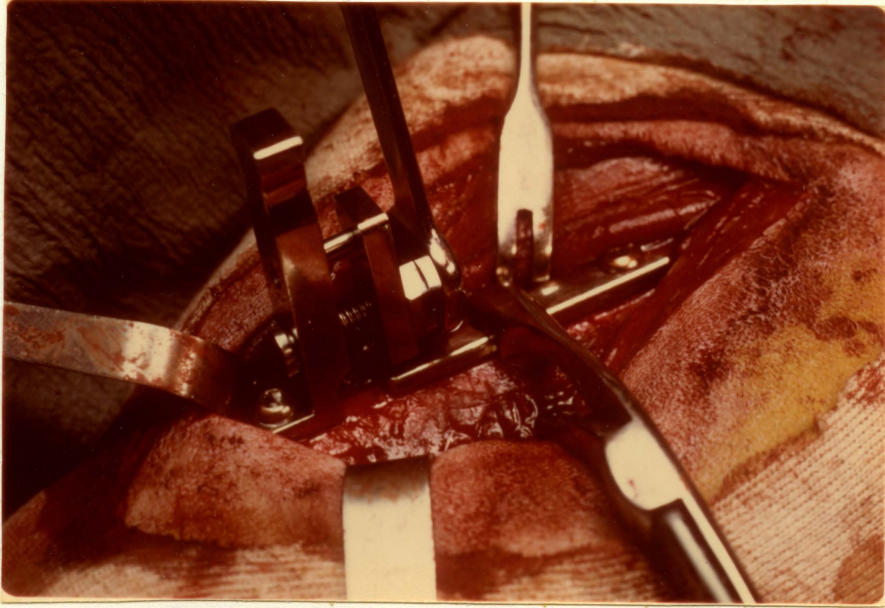
Fig. 45.   The compression wrench was used to tighten the
           compression device until some resistance was felt
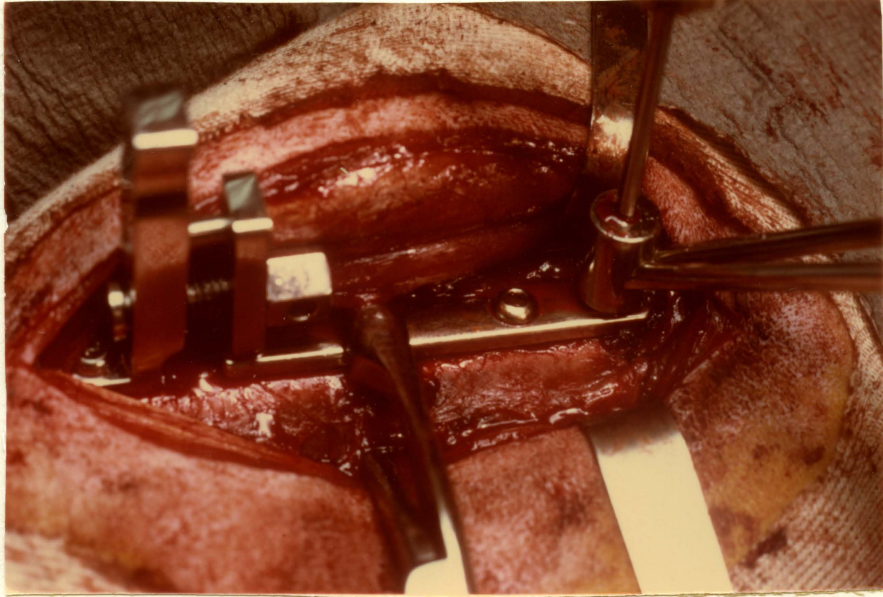
Fig. 46. A hole was drilled at the opposite end of the plate
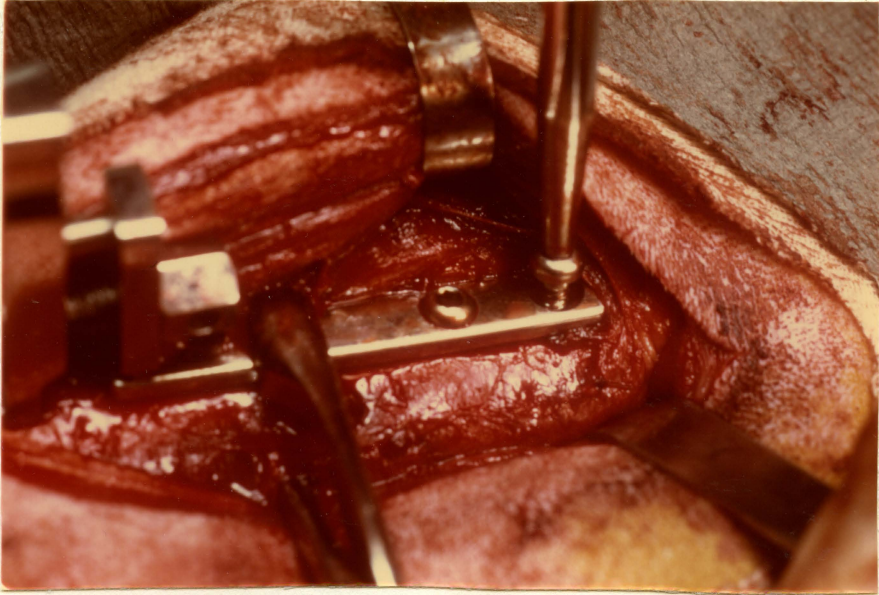
Fig. 47. A screw was placed in that hole
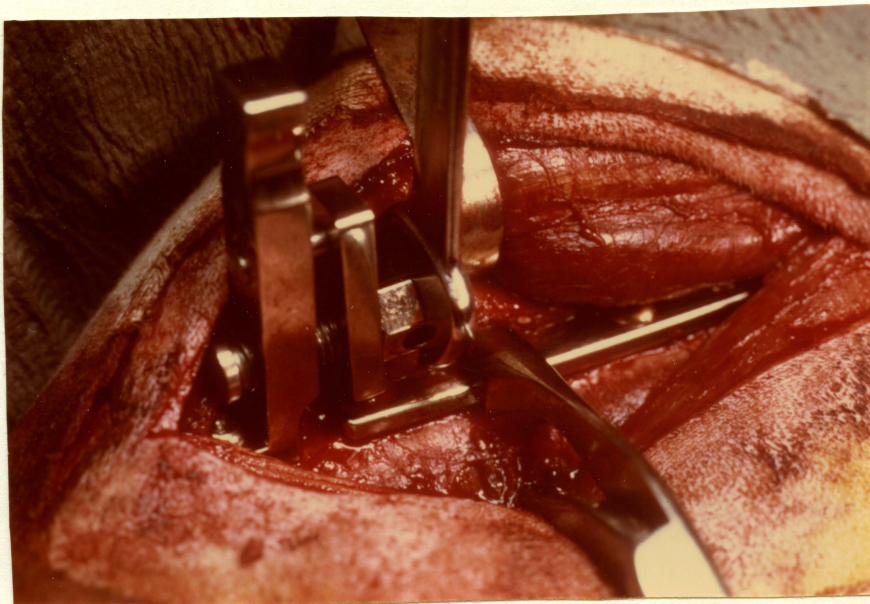
Fig. 48. The compression device was tightened until the
          fracture was well compressed
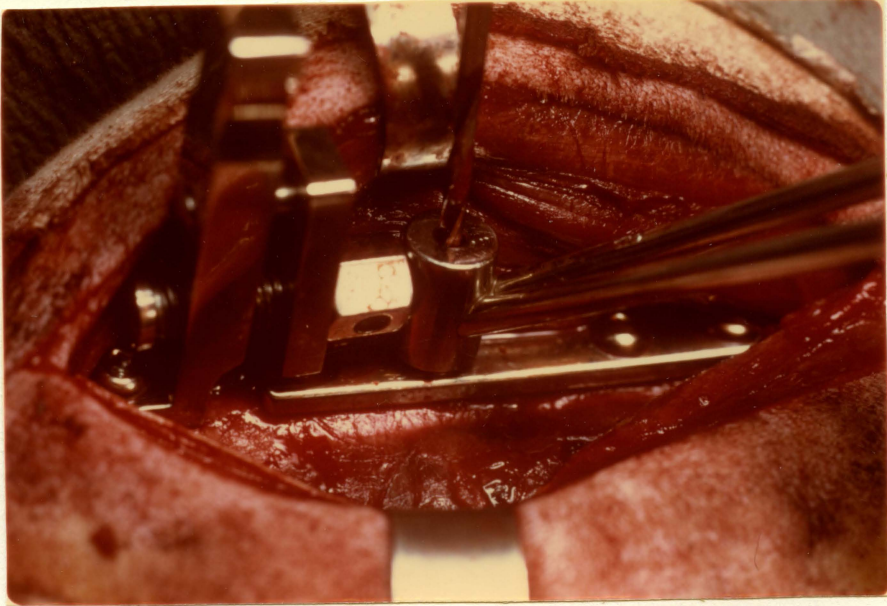
Fig. 49. A hole was drilled in the bone at the hole adjacent
to the compression device
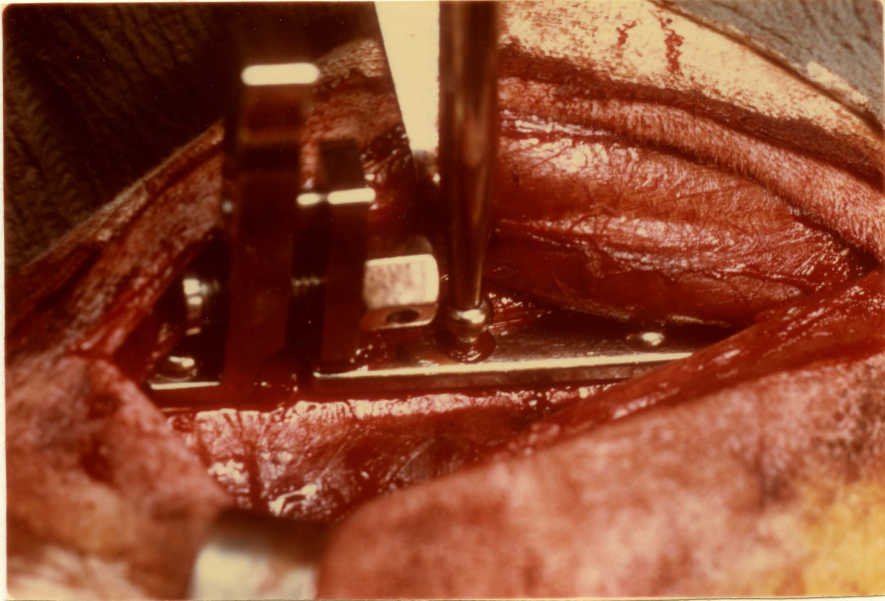
Fig. 50. An appropriate screw was placed in this hole
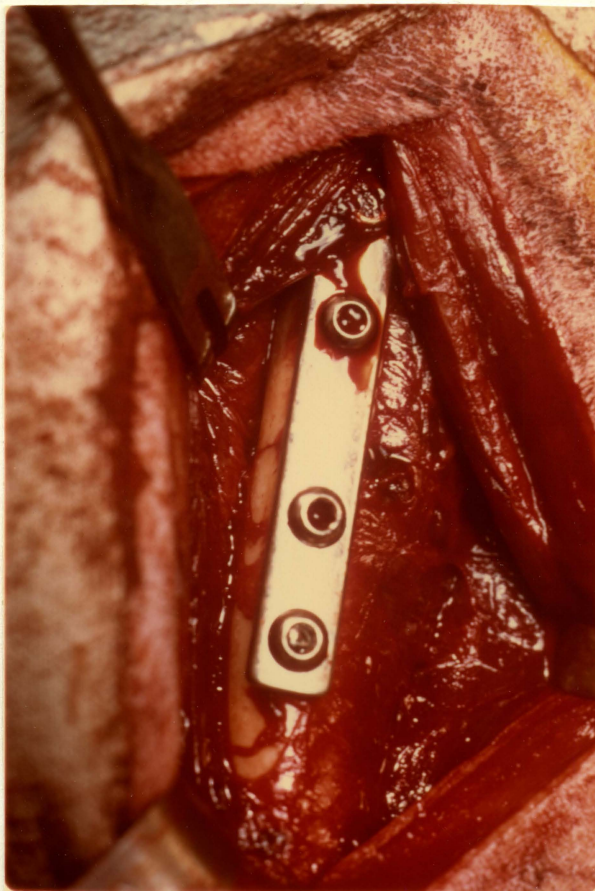
Fig. 51.   The completed plating

No bandages were used postoperatively. The dogs were maintained on penicillin-streptomycin for at least 5 days following surgery. The skin sutures were removed at 10-14 days postoperatively.

RESULTS

Group 1: 8-Week Observation Period

In group 1 the femurs were transversely fractured bilaterally in 4 dogs. The femoral fractures were repaired using an A.S.I.F. compression plate on the left and a Richards compression plate on the right.

Lameness in each case was classified into the following categories: normal ambulation, moderate limping, and carrying the limb.

All dogs in this group had no lameness and were bearing full weight at the time of euthanasia.

Gross evaluation

Wound healing of the surgical incisions was complete and free of drainage in all dogs in this group.

No irritation or discoloration was observed in the tissues adjacent to the plates.

Following removal of the femurs the soft tissues were stripped from the bones. Bending and rotational forces were manually applied to each femur with the plates in situ. All were stable.

In most instances there were varying amounts of fibrous tissue which had grown over the plates. This was cut through to expose the screws. The screws and bone plates were removed. The femurs were subjected to moderate manual bending and rotational forces. All were stable.

Radiographic evaluation

After the femurs had been grossly examined, they were split longitudinally with a band saw in an anterior-posterior direction. The medial and lateral halves were placed (cut surface down) side by side on a radiograph cassette along with the cut halves from the opposite femur. Radiographs were taken and evaluated. The femurs were evaluated to determine if the cortex had regained continuity and if the fracture line had disappeared.

Radiographically, there was continuity of the cortex of the femur under the plate on two femurs plated with Richards and two plated with A.S.I.F. On the contra-plate side two femurs plated with Richards and three plated with A.S.I.F. had regained continuity.

The fracture line was no longer visible under the plate on two femurs repaired with Richards and two repaired with A.S.I.F. On the contra-plate side, the fracture line was no longer visible on two femurs repaired with Richards and three plated with A.S.I.F.

In all cases the bone was more dense in a small circumscribed area surrounding the screw holes.

Microscopic evaluation

Longitudinal sections were taken of the plated side of each femur which included the fracture site and through the adjacent screw holes proximally and distally (Fig. 3). An

additional section was taken transversely through the most proximal screw hole of each femur, again on the plated side (Fig. 3). These sections were evaluated with both non-polarized and polarized transillumination.

The screw holes were classified as to whether there was fibrous tissue, fiber bone, or lamellar bone adjacent to where the screws had been and whether there was good or poor definition of the grooves created by the screw threads in the osseous tissue.

There was lamellar bone adjacent to where the screws had been except in the cases of two A.S.I.F. screw holes, which had fibrous tissue. There was good definition of the grooves in all cases (Figs. 52 and 53).

At the fracture site, evaluation was based on bony bridging of the fracture site and whether fiber bone, lamellar bone, or fibrous tissue was present.

Examination of the section of one femur repaired with a Richards plate showed that there was not bony bridging at the fracture site. One femur plated with A.S.I.F. did not have osseous bridging at the fracture site. One Richards and one A.S.I.F.-plated femur had fibrous tissue at the fracture site (Fig. 54). One A.S.I.F. and two Richards-plated femurs had fiber bone and lamellar bone at the fracture site. The rest had only lamellar bone at the fracture site.
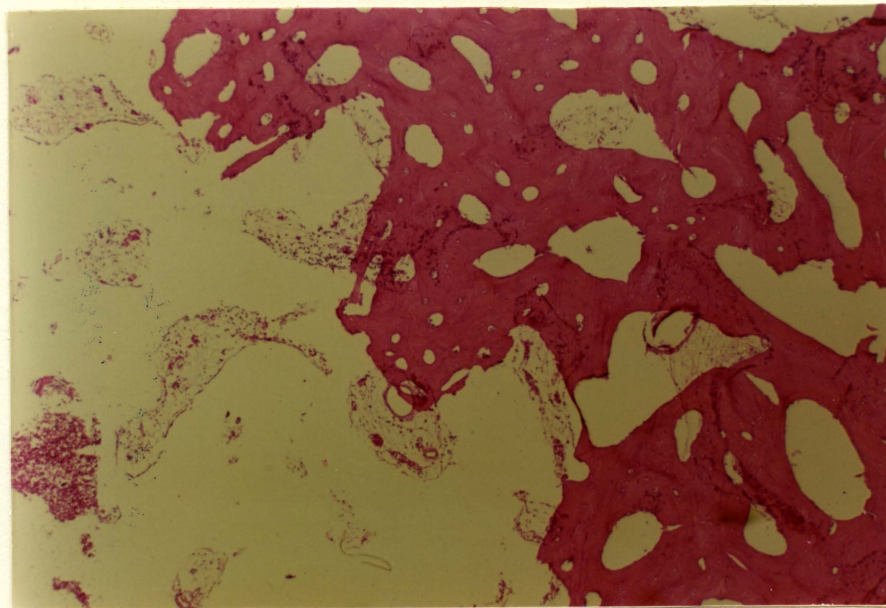
Fig. 52. Grooves made in bone by Richards screw in dog 104.
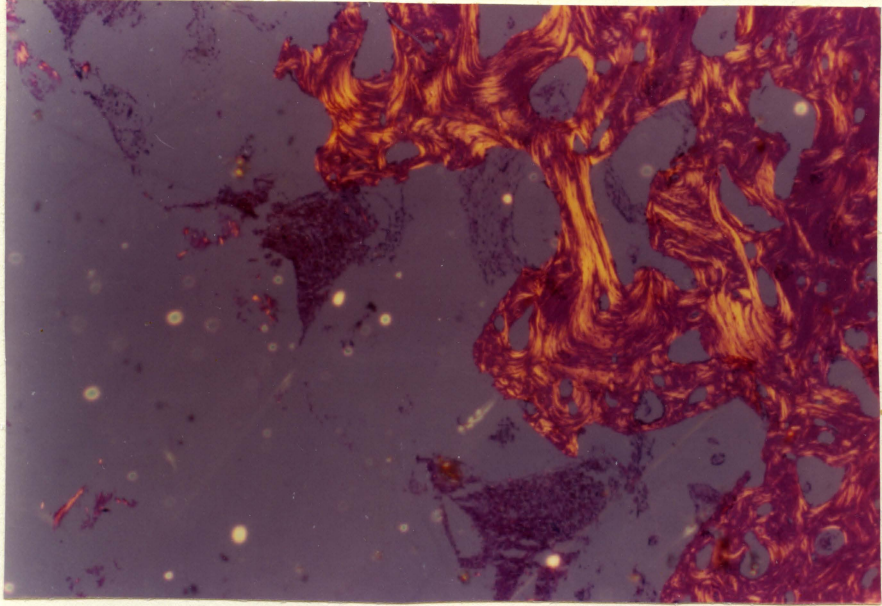Hematoxylin and eosin stain. X35

Fig. 53. Grooves made by Richards screw in dog 104. Polarized
light. Hematoxylin and eosin stain. X35
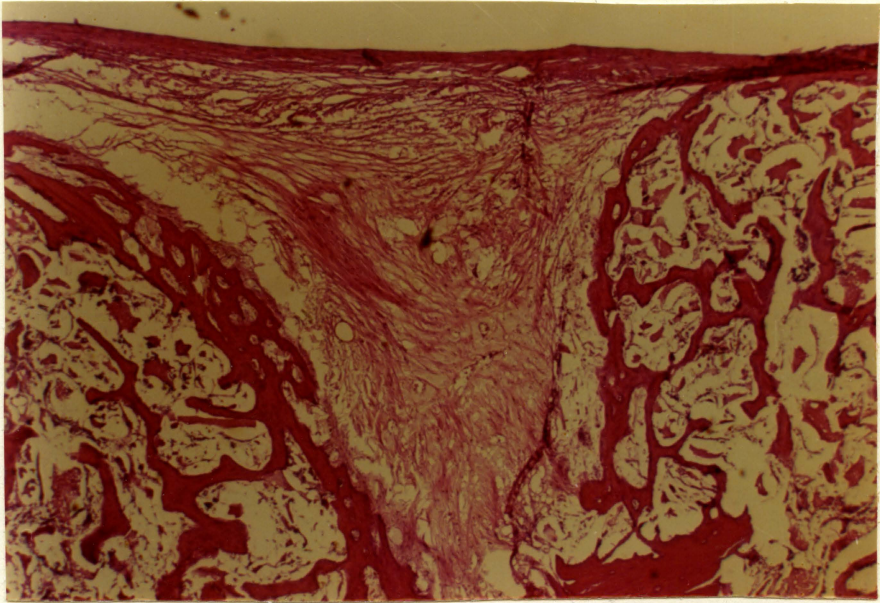
Fig. 54. Fibrous tissue at the fracture site of the left
          femur in dog 187. Hematoxylin and eosin stain.
          X35

Group 2:   16-Week Observation Period

In group 2 the femurs were transversely fractured bilaterally in 4 dogs. The femoral fractures were repaired using an A.S.I.F. compression plate on the left and a Richards compression plate on the right.

All dogs in this group had no lameness except dog 279, which carried its left leg.

Gross evaluation

Wound healing of the surgical incisions was complete and free of drainage in all dogs in this group. No signs of irritation or discoloration were seen in the tissues adjacent to the plates.

All of the femurs were stable to bending and rotational forces except the left femur of dog 279, which had fractured at the end of the plate.

There were varying amounts of fibrous tissue growth over the plates. After plate removal, the femurs were subjected to moderate manual bending and rotational forces. All were stable except for the above mentioned left femur of dog 279.

Radiographic evaluation

The femurs were split and radiographed as the ones in group 1 had been. The cortex was continuous in the contra-plate sections of all femurs except in both femurs of dog 281. The cortex was continuous on the plated side of all femurs in this group.

There was disappearance of the fracture line in all dogs except dog 281. The fracture line was still evident on the contra-plate side of this femur.

The new fracture at the distal end of the plate on the left femur in dog 279 was readily apparent (Fig. 55).

There were areas of increased density around the screw-holes in all cases, except the distal two holes in the left femur of dog 278. There was considerable lysis around these holes.

Microscopic evaluation

There was lamellar bone adjacent to where the screws had been except in the left femur of three dogs which had fibrous tissue around the threads (Fig. 56). There was good definition of the grooves made by the threads except for the left femur of dog 279.

Examination of sections of all femurs showed some bridging at the fracture site. All of the A.S.I.F.-plated femurs had lamellar bone at the fracture site, except one which was a combination of lamellar and fiber bone. Two of the Richards-plated femurs had lamellar bone (Figs. 57 and 58), one had a combination of lamellar and fiber bone (Figs. 59 and 60) and one had a combination of cartilage, fiber bone, and lamellar bone at the fracture site (Fig. 61).
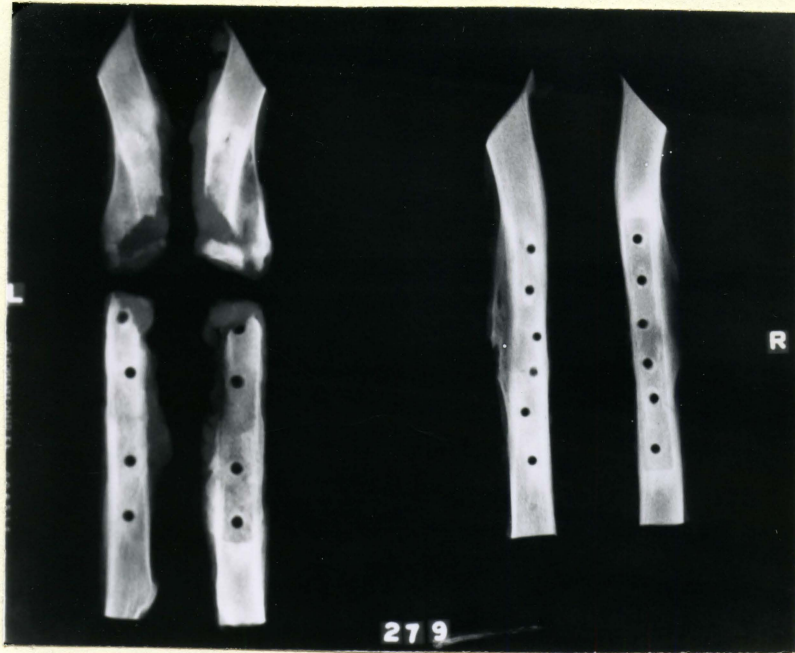
Fig. 55. Radiograph of split femurs of dog 279. Note frac-
ture of the left femur at the end of the plate
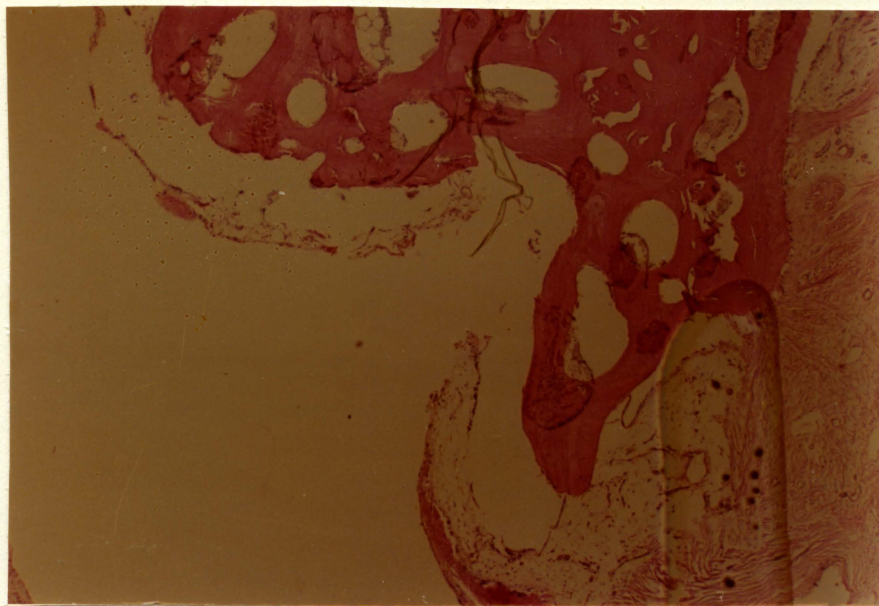
Fig. 56.   Fibrous tissue in the space between bone and where
           the A.S.I.F. screw had been in dog 40.   The fibrous
           tissue has separated from the bone during the
           processing.   Hematoxylin and eosin stain.   X35
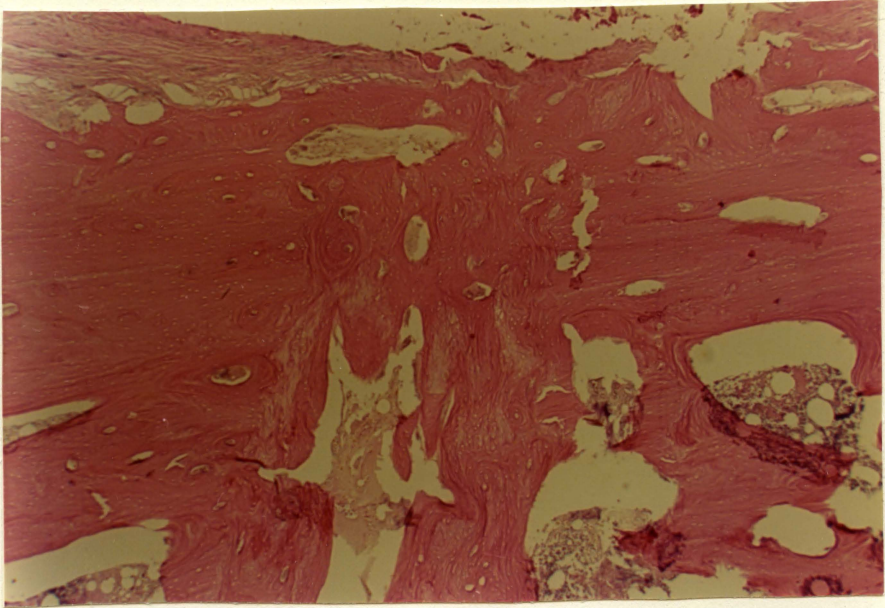
Fig. 57. Fracture site of the right femur of dog 279. Note lamellar bone, but different orientation at the fracture site. Hematoxylin and eosin stain. X35
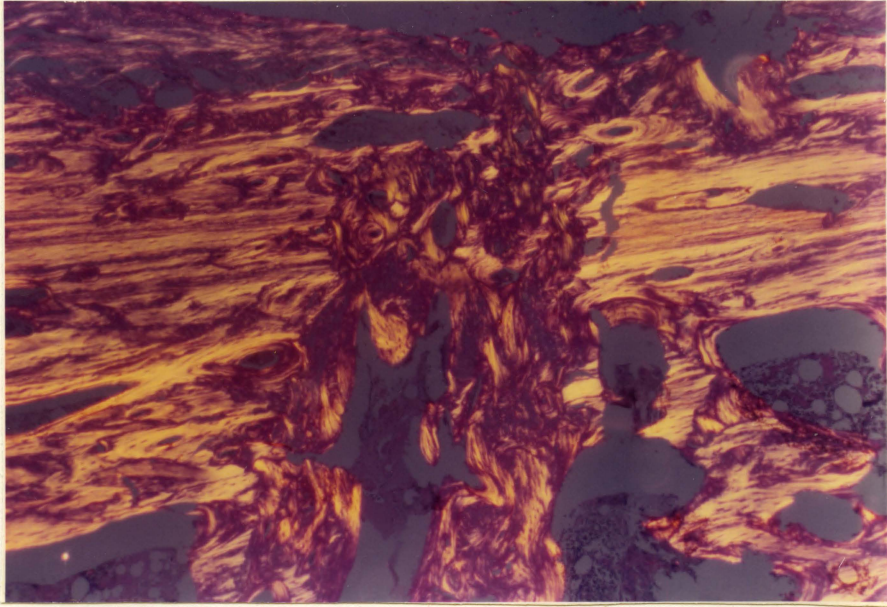
Fig. 58. Same as Fig. 57, but with polarized light
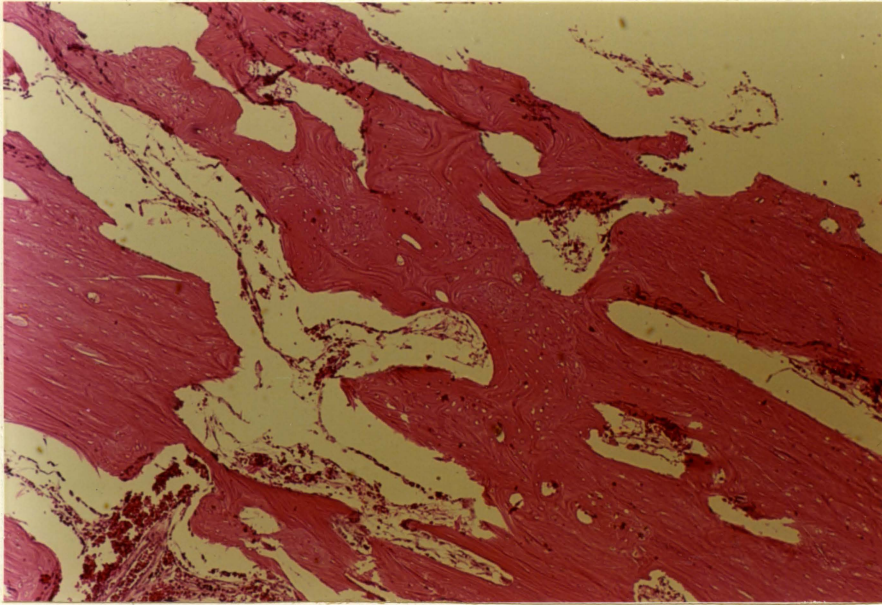
Fig. 59.   Fracture site of the right femur of dog 281. Note
           areas of lamellar bone (darker) and fiber bone
           (lighter). Hematoxylin and eosin stain. X35
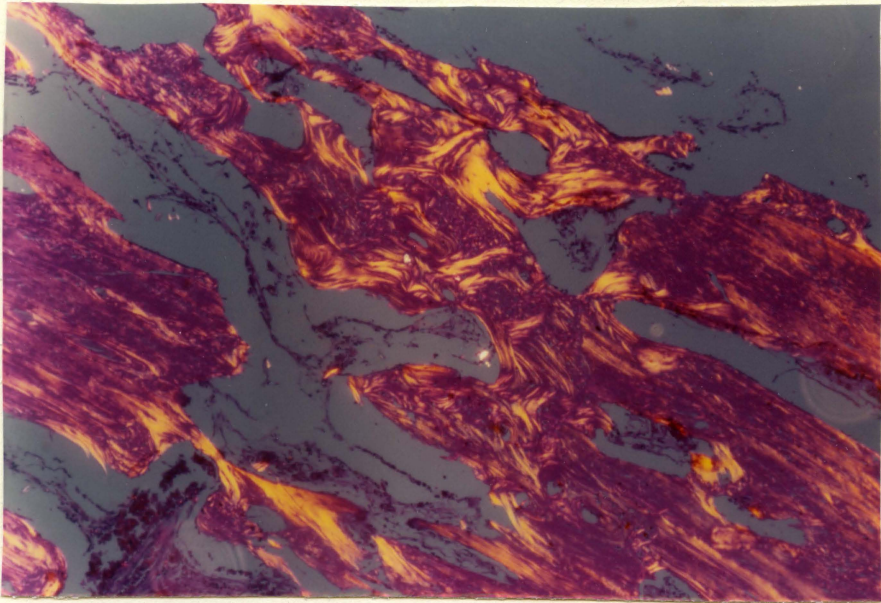
Fig. 60. Same as Fig. 59, but with polarized light. Areas
of lamellar and fiber bone are more readily apparent.
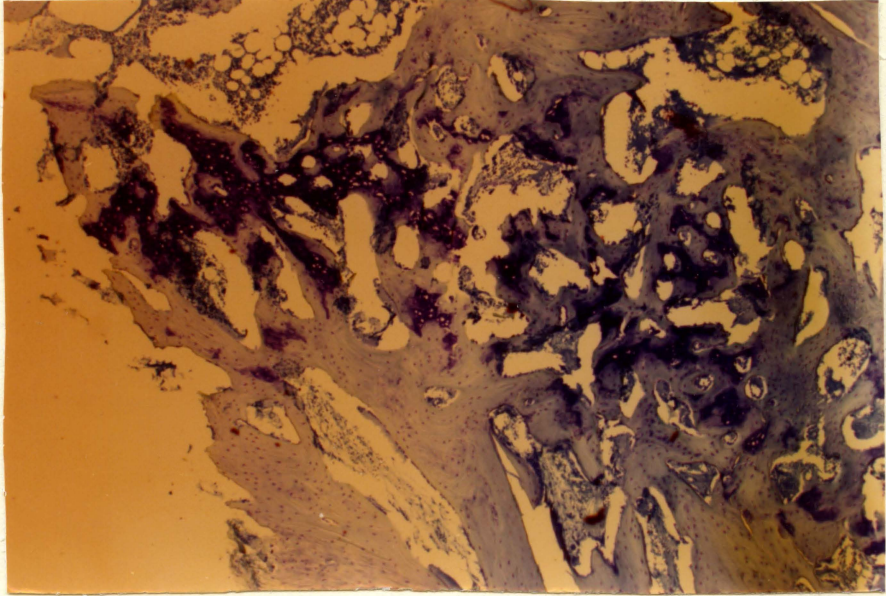
Fig. 61. Fracture site of right femur of dog 278. There are
          areas of lamellar bone, fiber bone, and cartilage
          present. The dark blue areas are cartilage.
          Toluidine blue stain. X35

Group 3: 40-Week Observation Period

In group 3 the femurs were transversely fractured bilaterally in 4 dogs. The femoral fractures were repaired using an A.S.I.F. compression plate on the left and a Richards compression plate on the right.

All dogs in this group had no lameness except dog 44, which carried its left leg.

Gross evaluation

Wound healing of the surgical incisions was complete and free of drainage in all dogs in this group. No signs of irritation or discoloration were seen in the tissues adjacent to the plates.

All of the femurs were stable to bending and rotational forces except the left femur of dog 44. There was motion at the fracture site when this femur was manipulated.

There were varying amounts of fibrous tissue growth over the plates. After plate removal, the femurs were subjected to moderate manual bending and rotational forces. All were stable except the left femur of dog 44. There was motion at the fracture site when only slight force was applied.

Radiographic evaluation

The femurs were split and radiographed as the ones from the previous groups had been.

The cortex had regained its continuity on both the plated

and contra-plated side in all femurs except the left femur of dog 44 (Fig. 62).

The fracture line had disappeared in both the plated and contra-plated side of all femurs except the left femur of dog 44.

There were areas of increased density around the screw-holes in all femurs except the holes in the left femur of dog 44. There were lytic areas around all of the screw holes of this femur.

Microscopic evaluation

There was lamellar bone right up to where the screws had been except the screw holes from dog 44, which had fibrous tissue between the bone and where the thread had been (Figs. 63 and 64). There was good definition of the grooves made by the threads (Figs. 65 and 66) except in the left femur of dog 44, where the grooves were poor. In several femurs there was a shell of bone surrounding the screw extending down into the medullary cavity (Figs. 67 and 68).

There was bony bridging at the fracture site, except in the left femur of dog 44. This femur had fibrous tissue at the fracture site. The right femur from dog 44 had a combination of lamellar and fiber bone at the fracture site. The rest had lamellar bone at the fracture site.

Fig. 62.   Radiograph of split femurs of dog 44.   Non-union has occurred in the left femur.   Note lysis around screw holes in left femur.
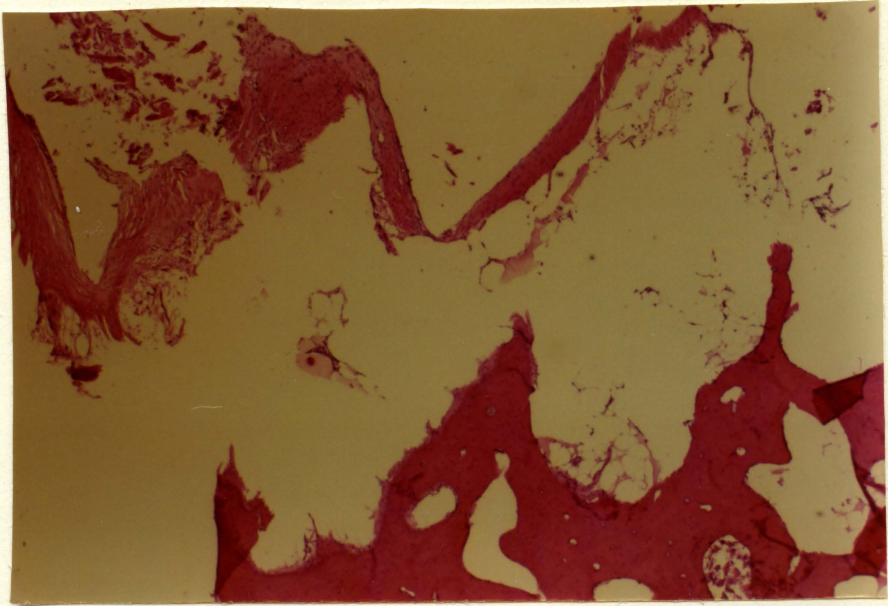
Fig. 63. Grooves made by Richards screw in right femur of
          dog 44. There is fibrous tissue in the space between
          the bone and where the screw had been. The fibrous
          tissue has separated from the bone during the process-
          ing. Hematoxylin and eosin stain. X35
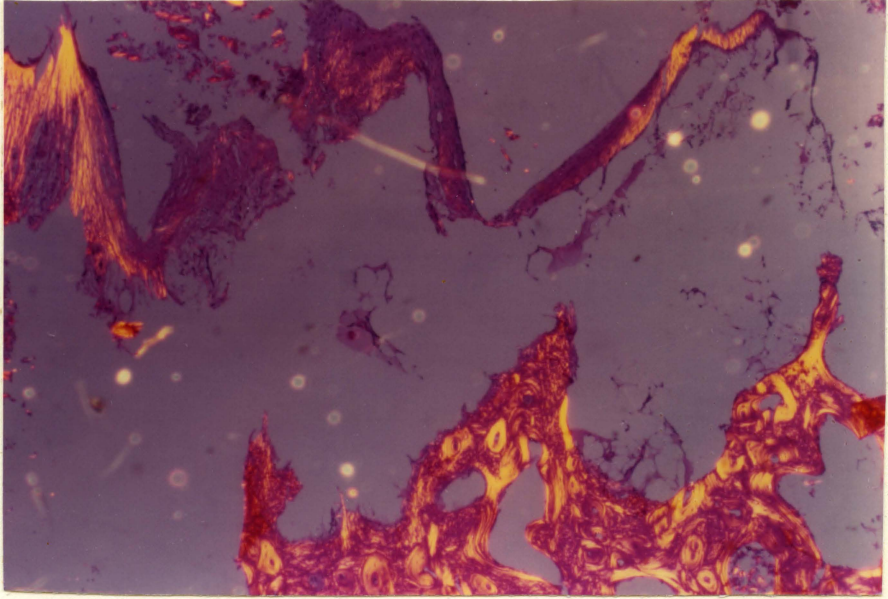
Fig. 64.   Same as Fig. 63, but with polarized light
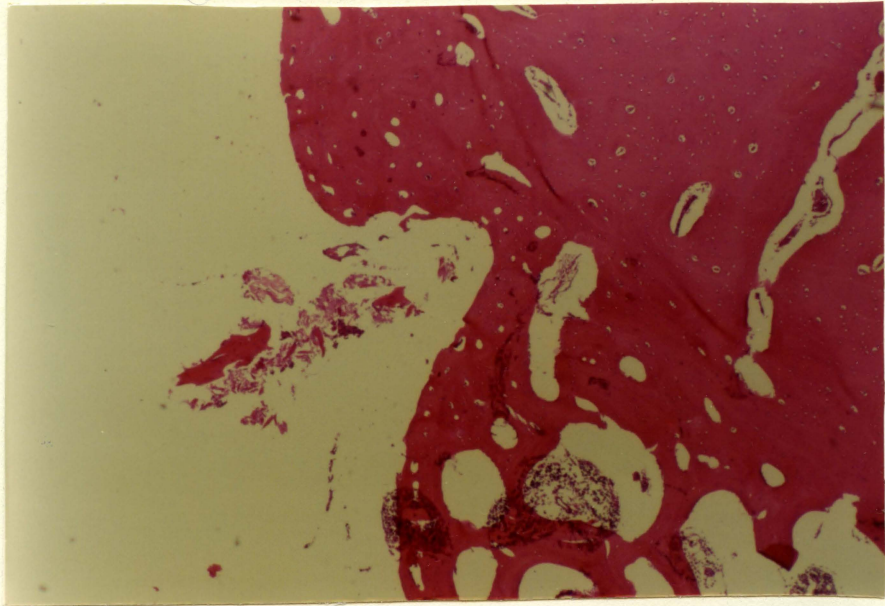
Fig. 65. Groove made by A.S.I.F. screw in dog 133.
Hematoxylin and eosin stain. X35
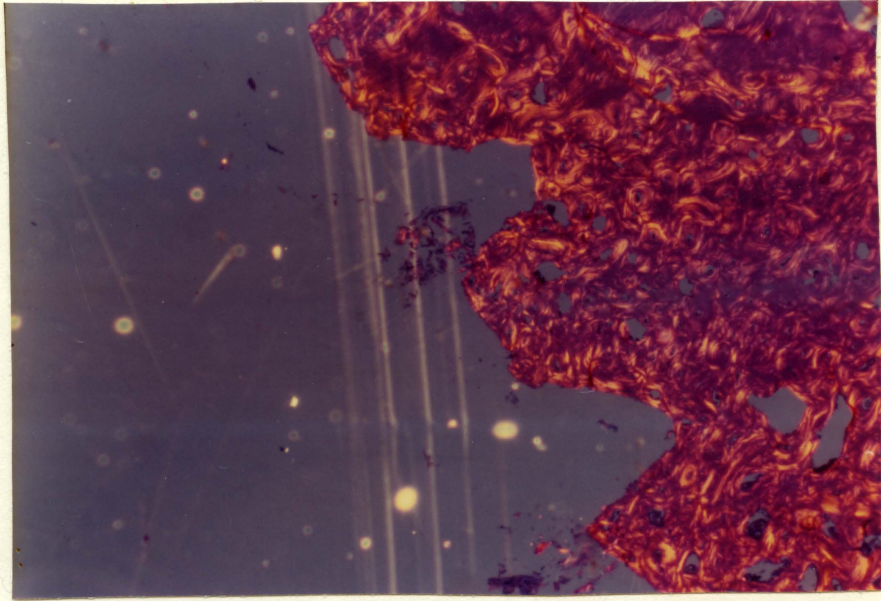
Fig. 66. Grooves made by Richards screw in dog 133. Polarized
light. Hematoxylin and eosin stain. X35
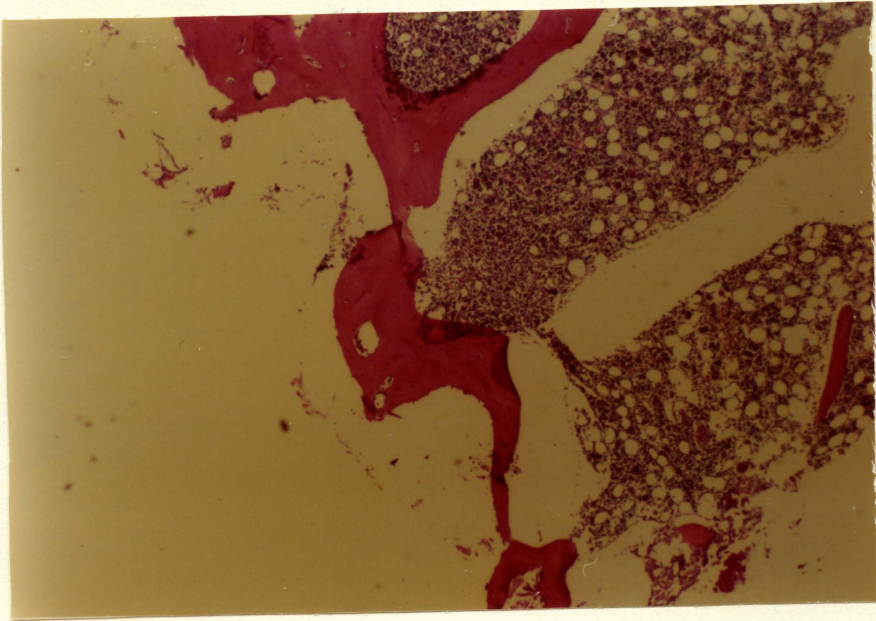
Fig. 67. Shell of bone surrounding the threads in the marrow
cavity of the right femur of dog 133. Hematoxylin
and eosin stain. X35
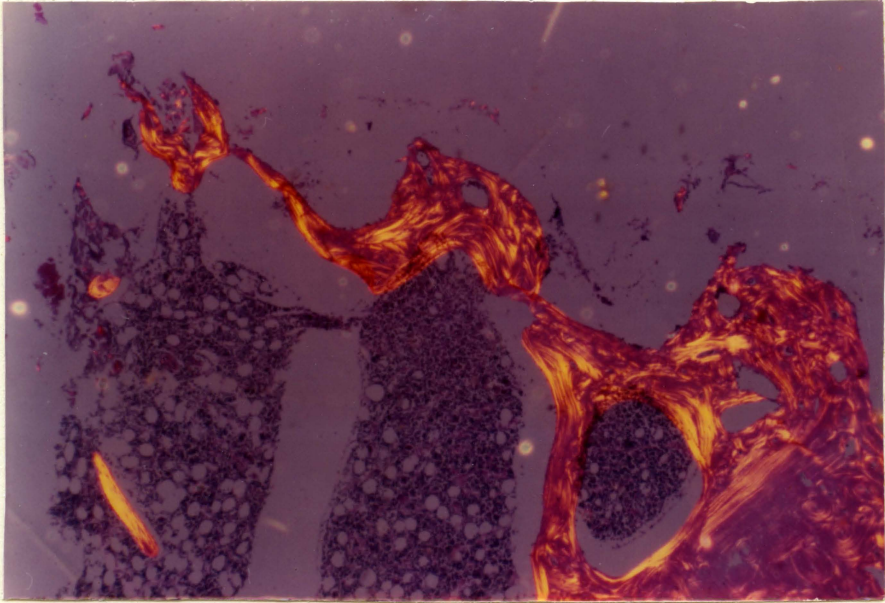
Fig. 68.   Same as Fig. 67, but with polarized light

DISCUSSION

This investigation, in which 12 dogs were used, was carried out to compare the results of femur fracture repair using Richards and A.S.I.F. compression plates. A review of the literature revealed that plating had been used for fracture repair since 1951. Plating with and without compression had been compared by Reynolds and Key in 1954. Many investigators used various types of compression plating equipment for repair of fresh fractures and delayed unions. No one had compared different types of compression equipment under similar conditions in a single investigation. This investigation attempted to do that.

Muller (1963) and Anderson (1965) stated that it was necessary to use a bone tap to cut threads in the bone for the screw in order to avoid necrosis and formation of fibrous connective tissue between the screw threads and the bone. This investigation compared the pre-tapped screws of the A.S.I.F. system with the self-tapping Richards screws.

A bone breaker, which was designed by the author, consistently produced simple transverse fractures. All previous investigators had used various types of saws to produce the fractures for their experiments.

The only dogs which showed lameness were those with non-union or refracture. In the 8-week group the dogs were walking

normally even if union had not occurred by gross, radiographic, and microscopic observations.

It was significant that, radiographically, in some cases the cortex had regained continuity and the fracture line had disappeared on one half of the femur, but not on the other. This may have been due to the stage of healing.

Grossly and microscopically, there was little reactivity to the bone plates. Plates and screws are made from type 316 stainless steel in both systems. Most of the fibrous tissue growth around the plates was likely due to periosteal stripping at the time of surgery.

The microscopic section taken of each fracture site represented only a minute segment of the 360° radius of the cortex. This fact helped explain some of the discrepancies in the gross, radiological, and microscopic results. When discrepancies occurred the radiological and gross evaluations were relied on more heavily.

In the cutting technique, it was not always possible to cut the sections of the fracture site such that both adjacent screwholes and the fracture site would appear on the same microscopic section. It was hoped that it would be possible to do that in order to have more screwholes for evaluation.

It was noted in the microscopic sections that if there was any indication that the screws had not held well, then there was more fiber bone and fibrous tissue at the fracture site.

The use of polarizing lenses was very helpful to help determine what was lamellar bone and what was fiber bone.

In one section toluidine blue was used to help demonstrate cartilage which was present and involved in the healing process.

In most microscopic sections of screwholes, it was noted that a shell of bone surrounding the threads of the screw extended down into the medullary cavity. This explained the increased density around the screwhole which had been noted radiographically.

In this study only three fractures on two dogs had not healed at the time of euthanasia. Two of these fractures were in one dog in the 8-week group. These could possibly have eventually healed with time. The other femur which did did not heal was an A.S.I.F.-plated femur in the 40-week group. Some of the screws had pulled out within the first two weeks after the repair of this fracture. One of the femurs which had been repaired with A.S.I.F. later fractured at the end of the plate. The original fracture site on this femur had healed. The new fracture was not significant in this study. Based on these results, there appeared to be no significant advantage of one compression system over the other as a method of fixation for fracture healing. The results did substantiate that compression plating is a good method of fracture repair.

The extra exposure required for the A.S.I.F. compression device was a disadvantage in the surgical procedure.

These results indicated more fibrous tissue between the screw threads and the bone with the A.S.I.F. than with the Richards screws. This was contrary to the opinions expressed earlier by Muller and Anderson. In this study, the extra time required to tap the threads for the A.S.I.F. screws was a disadvantage.

SUMMARY AND CONCLUSIONS

1. The purpose of this study was to compare healing of femur
fractures repaired with Richards and A.S.I.F. compression
plates. The holding effectiveness of the self-tapping Rich-
ards screws and non-self-tapping A.S.I.F. bone screws was
compared. The effect of the plates and screws on the bone
and surrounding tissues was evaluated.

2. The evaluation was made by comparing the results of frac-
ture healing clinically, grossly, radiographically, and micro-
scopically. The holding effectiveness of the screws was eval-
uated clinically and grossly. The screwholes were evaluated
radiographically and microscopically. The effects of the
screws and plates were observed grossly and microscopically.

3. Twelve dogs of mixed breeding were divided into 3 groups
and observed for 8 weeks, 16 weeks, and 40 weeks postopera-
tively. Each animal had transverse femur fractures created
bilaterally. The right femur fracture was repaired using
Richards compression equipment and the left using A.S.I.F.
compression equipment.

4. Lameness in each case was classified into the following
categories: normal ambulation, moderate limping, and carrying
the limb. Lameness was noted in two dogs. Both dogs were
carrying their left legs. Their femurs had been repaired with
A.S.I.F. plates. One was a non-union and the other femur

had fractured at the distal end of the plate. All of the other dogs had no lameness and were full weight bearing on both rear legs at the lime of euthanasia.

5. Each surgical incision was evaluated for wound healing and freedom of drainage. Healing was complete and drainage was absent in all dogs. On gross observation there was no irritation or discoloration of tissues adjacent to the plates.

6. Bending and rotational forces were manually applied to each femur with the plate still in place. Two femurs showed instability. Both were left femurs repaired with A.S.I.F. plates. One was a non-union and the other was a femur which had fractured at the distal end of the plate.

7. The plates were removed and the femurs were subjected to moderate bending and rotational forces. The same two femurs showed instability.

8. The femurs were split longitudinally in an anterior-posterior direction into plated and contra-plated halves. The halves were radiographed lying side by side on a cassette. The radiographs were evaluated to determine if the cortices had regained continuity and the fracture line had disappeared. There were 3 femurs where the cortex failed to regain continuity on both the plated and contra-plated side. Two of these were A.S.I.F.-plated femurs and one was Richards-plated. There were 2 femurs where the cortex did not regain continuity

on only the plate side. One had been repaired with a Richards plate and the other with an A.S.I.F. plate. There were three femurs with a lack of cortical continuity on only the contra-plate side. Two had been repaired with Richards and the other with A.S.I.F.

There were three femurs in which the fracture line did not disappear radiographically on both halves. Two were left femurs (A.S.I.F.) and one was a right femur (Richards).

There were two femurs in which the fracture line had not disappeared on the plated half. One of these was A.S.I.F.-plated and the other was Richards-plated. There were two right femurs (Richards) in which the fracture line had not disappeared on the contra-plate side.

9. Histopathological sections were taken through the proximal screwhole on each femur. These sections were evaluated and classified according to the type tissue adjacent to where the threads of the screw had been. The tissue types were either fibrous tissue, fiber bone, or lamellar bone. The sections were also evaluated for good or poor definition of the grooves in the bone created by the screw threads.

In seven screw holes there was some fibrous tissue present. Six of these were A.S.I.F. screwholes and one was a Richards screwhole. The remaining sections had mostly lamellar bone adjacent to where the screw had been.

Definition of grooves made by the threads was good in all

screwholes, except two A.S.I.F. holes. Fibrous tissue was present around these two screws.

10. Histopathological sections were made through the fracture site and extending proximally and distally to the screw holes adjacent to it. The sections were evaluated as to whether or not there was bony bridging of the fracture and if fiber bone, lamellar bone, or fibrous tissue was present.

There were three femurs in which bony bridging was not present. Two of these were left femurs (A.S.I.F.) and one was a right femur (Richards).

There were 14 femurs that had lamellar bone at the fracture site. Six of these were Richards-plated femurs and eight were A.S.I.F.-plated. Three femurs had fibrous tissue at the fracture site. Two were A.S.I.F. and one was a Richards. Six femurs had a combination of fiber and lamellar bone. Four of these were Richards femurs and two were A.S.I.F. One Richards-plated femur had a combination of cartilage, fiber bone, and lamellar bone at the fracture site.

11. The results of this study showed that the holding effectiveness of the A.S.I.F. screw, which required the threads to be cut in the bone with a tap, was not superior to the holding power of the Richards self-tapping screw. There was more fibrous tissue interposition between the bone and the screw with the A.S.I.F. screw.

There appeared to be no negative effects from leaving the plates and screws in place for as long as ten months.

Healing of fractures repaired with the two systems appeared to be similar. There was non-union with one A.S.I.F.-plated fracture. There was one dog in the 8-week group where neither femur had bony union at the time of euthanasia, although the dog was walking normally on both legs.

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