THE TRANS-OLECRANON APPROACH TO THE ELBOW JOINT AND ITS CLINICAL APPLICATION IN SMALL ANIMALS

by

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ABSTRACT

A posterior open approach to the canine elbow is described. Briefly, this approach consists of transecting the olecranon process and reflecting it and its muscle attachments proximally.

Advantages of the trans-olecranon approach are: 1) ease of approach; 2) attainment of maximum exposure; 3) perfect reduction of bone fragments is permitted; and 4) application of internal fixation is facilitated.

Results obtained are as good as, or superior to, those obtained by more conservative treatment of similar type elbow injuries.

Indications for use of this approach are: 1) dislocations of the elbow which cannot be reduced by more conservative procedures; 2) fractures of the elbow, either recent or old, which cannot be adequately reduced by ordinary surgical procedures; and 3) removal of broken internal fixation and replacement with new internal fixation.

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INTRODUCTION

In small animal practice, dislocations and fractures involving the elbow joint are not uncommon. The management of recent dislocations and not too severely comminuted fractures has been relatively successful. The treatment of older injuries, or severely comminuted fractures, has met with less success. Muscle contracture, soft tissue swelling, fibrous callus, and/or primary bone callus, are all major hinderances to the successful reduction of dislocations and fractures of this articulation.

A surgical approach which provides adequate exposure would permit greater manipulation of the bone fragments. Near perfect realignment of these fragments, particularly when articular surfaces are involved, is necessary for good functional results. Failure to obtain near perfect reduction frequently terminates in lameness, loss of range of movement, or ankylosis.

The posterior approach provides the necessary exposure for repair of these difficult elbow injuries. This approach is accomplished by one of two techniques: 1) partial or complete severance of the triceps tendon, or 2) transection of the olecranon process of the ulna. In small animals, to achieve maximum exposure of the posterior aspect of the elbow, the insertions of all four heads of the triceps muscle must be severed. Since severance of the

tendon of the triceps at or near the insertion on the olecranon process offers no additional exposure and does add greatly to the postoperative problems, the transolecranon approach was selected for further investigation.

REVIEW OF THE LITERATURE

Human Medical Literature

The usual treatment of dislocations and fractures of the human elbow is by closed reduction, traction, and external splintage. Many surgeons feel the results obtained by closed reduction are as good as those obtained by open reduction. Others are of the opinion that the increased risk of osteomyelitis offsets any advantages gained by open reduction (1).

The usual British reserve is reflected in the treatment of fractures by some of their surgeons. In commenting on the Stader-type fixation apparatus, Watson-Jones (2) wrote, "This is indeed an age of mechanisation and we should beware lest surgeons forget to use their hands; but still more should we beware lest surgeons forget to use their comprehension." Referring to the practice, during World War II, of using intramedullary pins, little or no external splinting, and early mobilization and use of the limb, he remarked, "Necessity, in this case, was the mother of so fertile an invention that sound judgement was threatened."

On repair of elbow fractures Watson-Jones (3) states that closed manipulative reduction gives better results than operative reduction. "There can be little doubt that the worst treatment of comminuted intercondylar

fractures of the humerus is extensive operative reduction with internal fixation by triradiate plates and many screws."

He does concede that a fellow coutryman, Evans, offers a compromise between operative reduction and manipulative reduction. Evans (4) suggests treating "Y" fractures of the humerus by means of a single transverse intercondylar screw. The remaining supracondylar-type fracture is reduced by closed manipulation and a pressure bandage applied to maintain reduction.

In 1955 Evans (5) wrote, "The accepted methods of treatment [of supracondylar-Y fractures] are not satisfactory. Manipulation is uncertain, so that the final function is often poor." He goes on, "Accurate reconstruction is perhaps the least satisfactory method of all, for it entails wide exposure, with consequent damage to important muscle groups." He does feel that if operative reduction is attempted the posterior approach should be favored.

There are many surgeons who recommend open reduction under certain conditions. As early as 1906 Haines (6) advocated open reduction for all extensive fractures of the elbow. Benjamin and Mayo (7) were also on record as supporting this procedure. Adams (8) wrote that when one adequate attempt at closed reduction fails, to prevent further traumatizing of tissues, an open reduction is indicated. Homans (9) advised early open reduction when extensive dearrangement of the articular surfaces occurs. He cautions against closed reduction when surgical reduction is indicated. Venable and Stuck (10) recommend open reduction and internal

fixation when closed reduction fails to correct the displacement or maintain reduction.

In a study of thirteen cases of fractures of the epiphysis of the lateral humeral condyle which resulted in nonunions following conservative treatment, Jeffery (11) concluded in part: 1) open reduction and internal fixation with a screw is indicated, simple soft tissue suturing is inadequate; 2) imperfect closed reductions should be viewed critically and open reduction with internal fixation should be considered; and 3) "Union must be established unequivocally by radiographs."

The importance of perfect anatomic reduction cannot be over emphasized. Wilson (12) believed that if proper reduction is achieved, bony union will result. Smith and Joyce (13) wrote, "...adequate blood supply and complete immobilization are of equal importance in securing solid union." They also felt that if an open reduction is performed, firm internal fixation should be inserted.

Speed and Knight (14) wrote:

> The elbow joint is a particularly complicated articulation and, as a consequence, minor disturbances in anatomic alignment produce major disturbances in function. Displaced fractures of the condyles cannot, regardless of type, be satisfactorily reduced, nor held, even if reduced, by external immobilization. Assuming that future function is based upon anatomic restoration, the majority of fractures of the humeral condyles should be replaced under direct vision and held in place by internal fixation.
>
> Both in childern and adults, "the golden hour" for surgery is lost forever when operative reduction is delayed by indecision while awaiting the outcome of closed or conservative procedures. There are, of course, extenuating circumstances which postpone surgery,.... But, the general rule should be "as soon as safe."

Numerous surgical approaches to the elbow are described in the human medical literature, summaries of which appear in the works of Speed and Knight (14), Nicola (15), Thorek (16), and Mosely (17).

Van Gorder (18) wrote, "...the easiest and most effective method of accurately reducing supracondylar "T" fractures...is through a posterior approach to the elbow." The reasons given for this are: 1) more adequate exposure is obtained; 2) a wider selection of internal fixation is allowed; 3) dissection is through tissues containing no important structures; and 4) it is the only approach which gives a clear view of all articular surfaces of the joint.

Knight (19) recommends open reduction with internal fixation and early mobilization as the treatment of choice for nearly all articular fractures of the humeral condyles. Adequate exposure is absolutely necessary since all fragments must be completely visualized. Neither the lateral nor the medial approach, or a combination of these, should be used since they do not give sufficient exposure. He uses the posterior approach routinely. Knight wrote:

> Fortunately, the operative approach to the [elbow] joint is relatively bloodless. Practically any patient who is a reasonably good risk for general anesthetic will be a satisfactory canidate for operative restoration of the joint.

Blanchard (20) and others (21-24) have used posterior approaches to reduce long-standing dislocations of the elbow.

Murphy (25) and MacAusland (26) used posterior approaches in arthroplastic operations on the elbow.

In human orthopedic surgery, fractured or transected

olecranon processes have been repaired by use of absorbable and non-absorbable materials. In the latter case, Murphy (25) used wire, Rush and Rush (27,28) and MacAusland (29) used intramedullary pins, and Blanchard (20), MacAusland (29), and Harmon (30) used screws.

MacAusland (29) states that the use of intramedullary pins or screws is an improvement over absorbable sutures. It is possible to obtain near perfect apposition of bone fragments, particularly when bone screws are used. The threads of the screw tightly engage the fragments and close the fracture-gap. The greatest advantage afforded by this means of immobilization is the shortening of the convalescence period from months to weeks.

Since the reintroduction of intramedullary pinning by Kuentscher (31,32) in 1940, there remained the fundamental question of the effects of intramedullary pinning on the healing of fractures (33,34). Fitts, et al. (35) in part concluded:

> The insertion of an intramedullary wire into the dog's ulna fractured experimentally produces periosteal callus over an area far removed from the fracture site. This callus reaches its maximum on the roentgenogram at 4 to 6 weeks and is gradually absorbed. It appears to have little effect on the healing of the fracture and is not the result of destruction of the marrow. We postulate that this callus is caused by pressure of the wire on the inner cortex and that its disappearance is due to absorption of bone and the release of pressure.
>
> Fractures of the distal half of the ulna heal more rapidly if a wire is inserted through the medullary cavity past the fracture. The more rapid union is probably due to better immobilization which is effected by the wire and not to any callus stimulating effect of its presence.
>
> It is probable that the presence of an inert foreign body in the medullary cavity does not significantly delay or speed fracture healing.

Joint stiffness and resultant loss of full range of joint movement are all too frequent sequelae to injuries near or of articulations. This has been attributed to muscle atrophy following immobilization of the injured limb. The degree of stiffness is reduced by active use of the affected limb during the healing process. Less muscle atrophy occurs and muscle activity helps to maintain circulation and reduce edema (36).

According to Watson-Jones (37) joint stiffness is not caused by immobilization but rather by functional inactivity. He feels the extent of stiffness is directly related to the amount of functional inactivity of the part. The reason given for this is the formation of adhesions between muscle groups and in the joint capsule itself. These adhesions were due to venous stasis resulting from muscular inactivity. This author found the range of joint movement decreased with passive stretching and forceful manipulation of stiff elbows. The range steadily decreased as this type of treatment was continued. He concludes that mobilization of stiff joints should be accomplished solely by the patient's own activity.

In a study of elbow and humerus injuries suffered by British airmen in flying and non-flying accidents, Doran (38), found that flying accident injuries took longer to heal. Furthermore, only half as many of these elbows gained full range of movement as compared to non-flying accident injuries. The increased severity of flying accident injuries was given as the reason for the differences.

Since all were traumatic injuries and the ages, sex, and other factors were similar, Doran divided the causes of joint stiffness into two major groups: 1) articular, including fibrous or osseous ankylosis, bony obstruction due to detached articular fragments, and shortening of the joint capsule; and 2) muscular, including myositis ossificans, loss or diminution of muscle contraction and elongation, and partial or complete loss of muscle function as a result of gross muscle tissue destruction or loss of nerve innervation.

Perkins (39) wrote, "All joints not immobilized by splintage should be moved actively by the patient. Since movement is so desirable, the splint should be shortened to its minimum so as to free as many joints as possible." He believed the main reason healthy splinted joints stiffened is that the muscles have lost their ability to elongate. To support this contention, he cites the return of full range of movement in normal joints, stiff as a result of splinting, when the muscles are elongated. He concludes, "Muscle activity confers three blessings: 1) it promotes a normal circulation in the limb; 2) it preserves the extensibility of the muscles and so avoids joint stiffness; and 3) it stimulates the formation of callus."

Veterinary Medical Literature

The earliest available veterinary reference to recommend a specific treatment for humeral condyle fractures was published in 1934 and again in 1939 (40,41). Schroeder stated in these articles, "This is one of the more difficult injuries to treat and yet it is suprising that healing with perfect

function does occur. He advised closed reduction, application of coaptation pads to the condyles to maintain the reduction, and immobilization with a Thomas splint, the elbow being held in extension.

He goes on:

> We always attempt accurate reposition and alignment, and then arrange splintage and dressings with the purpose of maintaining the reduction. A perfect anatomic result has not yet been attained. Functional results have been better than expected.

Although the merits of open reduction and application of internal fixation for repair of elbow fractures are widely recognized, this recognization has not been universal. There are veterinary practitioners who rely on conservative treatment for repair of these elbow injuries (42).

According to Brinker (43), these three important principles should be observed in the treatment of fractures near or involving articulations: 1) good alignment of bone fragments is necessary, particularly if articular surfaces are involved; 2) the fixation apparatus should not penetrate the joint capsule or articular surfaces; and 3) there should be uninterrupted immobilization of the bone fragments.

In discussing intercondyloid T and Y fractures of the humerus, Brinker continued, "Open reduction is difficult and often results in added adhesions and contraction of the capsule, thus contributing to partial loss of movement or permanent stiffness." Later, he felt that in severely comminuted or old unreduced fractures, the results obtained by closed reduction or by limited surgical approaches were unsatisfactory (44).

Lateral and medial approaches to the distal end of the humerus are described in the veterinary literature (43, 45,46). These approaches can be used to facilitate reduction of condyle fractures.

Wamberg (47) sates that surgical reposition is required in certain intra-articular fractures of the humerus.

Nielsen (48) wrote:

> A rather frequent lesion is the characteristic fracture of the humeral lateral epicondyle with luxation of the medial epicondyle. Open reduction and fixation with a single transverse screw restores normal function to the joint, while conservative treatment results in totally deformed joints.

Brinker (43) originally suggested treating simple condyle and intercondyloid fractures of the humerus by use of the Kirschner pin, clamps, and bars. Later he advised either closed or open reduction of condyle fractures and immobilization with a bone screw inserted transversely through the condyles. Repair of intercondyloid T and Y fractures of the humerus was accomplished by means of a bone screw inserted transversely through the reduced condyles. The remaining supracondylar-type fracture was immobilized by an intramedullary pin inserted through the greater tubercle (lateral tuberosity), the length of the humeral shaft, and into the medial condyle. Normally, early mobilization was encouraged and external splinting was not required (44,45).

Knight (49) advised open reduction via the lateral approach for humeral condyle fractures. He inserted a bone screw through the condyles to immobilize the bone fragments. Hoerlein (50) used a Kirschner pin and clamps

to immobilize condyle fractures. He attached the pin to a Thomas splint if further immobilization was required as in the case of T or Y fractures. Stader (51) recommended a modification of the Stader fixation apparatus to immobilize humeral intercondyloid and supracondylar fractures.

The use of bone screws was reintroduced to the veterinarian profession in 1943 (52). Larsen, a Danish veterinarian, was reported by Nielsen (48), to have used bone screws and plates to repair fractures in small animals in 1910.

In 1949 Nielsen (48) wrote:

> If osteosynthesis is necessary in near-joint fractures screws are preferred inasmuch as the smaller fragment has to be attached to the rest of the bone with precision. In the case of diaphyseal fractures one may often obtain good function in spite of moderate displacement. On the other hand, a slight shifting near a joint or in a joint surface itself may have disasterous effect. In addition to this, the fixation must be of such a character that one is able to permit the patient to perform movements of the joint as early as possible in order to avoid ankylosis.

It is interesting to note that in 1934 Schroeder suggested the use of a screw to immobilize a humeral condyle fracture (40).

In 1940 Kuentscher reintroduced intramedullary pin fixation to the medical profession following experimental studies on small animals (31,32). After World War II numerous articles appeared in the veterinary literature on this method of immobilization (53-66).

The non-threaded intramedullary pin has been recommended for immobilization of fractures of the proximal end of the ulna (43, 45, 46). Knight and Pittaway (67) reported

the failure of a non-threaded intramedullary pin to immobilize a fracture olecranon process due to bending of the pin. Cholvin (68) feels delayed union often results in this type of fracture because complete immobilization is not maintained by the non-threaded intramedullary pin.

In 1949 Nielsen (48) reported using bone screws to immobilize a longitudinal fracture of the olecranon process, but only recently have articles appeared on this method of fixation for transverse fractures of the olecranon process and proximal end of the ulna (49,69,70).

Recent elbow dislocations can usually be successfully reduced by a combination of manipulation and traction (71).

Stader (72) wrote:

> In my experience, skeletal traction is the only method that will bring about sufficient direct traction to accomplish a reduction without serious damage to the soft tissue of the joint.

The reduction of long-standing elbow dislocations is usually difficult (73). In these cases, Leighton suggested an open approach. He then uses a pair of scissors, as a lever, to reduce the dislocation.

In human orthopedic surgery, the posterior approach to the elbow is accomplished by one of two techniques: 1) partial or complete severance of the triceps tendon, or 2) transection of the olecranon process of the ulna (14-17).

Dinsmore (74) wrote:

> Tendon injuries in small-animal practice constitute a problem which is not easily solved. The apposition of severed tendon is only a part of the concept of tendon surgery, where postoperative management of animal patients becomes a greater problem than actual repair.

Mason's research (75) indicates that tendons should be completely immobilized for about sixteen days following repair. After this period of time restricted use of the injuried limb should be permitted.

Armistead (76), from his work with severed Achilles' tendons in rats, in part concluded:

> ...that tendon which was divided regained strength equal to that of its muscle by the eigth week after operation....It is important to note, however, that the strength of the entire unit was not as great as that of the corresponding normal unit until the twenty-second week after operation.

ANATOMY OF THE CANINE ELBOW

The elbow joint is actually composed of three separate and distinct articulations. These are the humero-radial, the humero-ulnar, and the proximal radio-ulnar articulations (77-79). The humero-radial articulation is an arthrodial or gliding type joint, the humero-ulnar articulation is a ginglymus or hinge type joint, and the proximal radio-ulnar articulation is a trochoid or pivot type joint. Since these three separate articulations function as a unit, the elbow joint or cubital articulation is considered to be a ginglymus or gliding type joint (77).

Bradley and Grahame (79) wrote:

> The joint-capsule (capsula articularis), surrounding all three components of the joint, is strong in front where it is associated with the annular ligament of the radius, but weak and roomy behind, where it is supported by the triceps and anconeus muscles.

The medial and lateral collateral ligaments, essentially thickenings in the fibrous joint capsule, arise from the medial and lateral aspects of the radius and ulna, respectively. The annular ligament, also only a thickening of the joint capsule, aids in holding the proximal ends of the radius and ulna in apposition. It arises from the lateral surface of the head of the radius, crosses the flexor surface of the articulation, and attaches to the medial surface of the ulna in the region of the coronoid process.

There are two other ligaments of somewhat lesser importance. The oblique ligament, which is located on the flexor surface of the joint, extends from the distal end of the humerus to the proximal end of the radius. The olecranon ligament extends from the lateral aspect of the olecranon process to the medial aspect of the lateral condyle.

The interosseous ligament (membrane) consists of short fibers of collagenous tissue passing between the radius and the ulna at the proximal end of the radius. Although not incorporated in the joint capsule of the elbow, this ligament is nevertheless important, it serves to unite closely the radius and ulna.

Plates 1 and 2, reproduced radiographs, show the normal radiographic anatomy of the osseous structures of the canine elbow. Rarely, atypical sesamoid bones may be found in the region of the elbow. Stiern (80) reported three such cases of sesamoid bones (patella cubiti) in the triceps tendon.

MATERIALS AND METHODS

Five apparently normal adult dogs, each weighing from fifteen to twenty-five pounds, served as experimental animals. Prior to surgery, all elbows exhibited full ranges of movement and functionally appeared normal. Gross examination after opening the joint capsule and before producing the fractures, verified that the osseous structures were essentially normal.

The injured elbows of twelve dogs presented at the small animal clinic, College of Veterinary Medicine, Michigan State University, were repaired using the trans-olecranon approach. These elbow injuries included one old dislocation, seven long-standing condyle fractures, and three T or Y fractures. In addition, in one case a broken intercondyloid screw was removed and a new one inserted. The injuries were from one day to three months old at the time of surgical correction. The dogs ranged in size from a Manchester Terrier to a German Shepherd. The ages ranged from four months to ten years.

Preoperative Procedure

Pentobarbital Sodium was used as the general anesthetic. The leg to be operated was clipped from the carpus to above the shoulder and was then held suspended above the operating table, either by an assistant or by a gauze bandage tied to a transfusion stand.

The limb was thoroughly scrubbed by hand from the carpus to above the shoulder a minimum of four times, using Liquid Germicidal Detergent (Parke, Davis and Company, Detroit), diluted one part in three parts water. Following the last scrub a thin layer of the dilute detergent was spread over the leg. This was removed with a sterile surgical sponge just prior to making the skin incision.

Strict adherence to aseptic technic was considered an absolute necessity. The surgeon and his assistant(s) wore caps and masks and thoroughly scrubbed their hands and arms to above the elbows. They then put on sterile gowns and gloves. The surgeon held a sterile towel into which the suspended leg was allowed to drop. The lower foreleg and carpus were tightly wrapped in the sterile towel. Throughout this procedure care was taken to prevent the leg and sterile towel from touching the contaminated surroundings. Sterile drapes were placed above and around the shoulder. These drapes were of sufficient size to cover the patient and most or all of the operating table.

Surgical Approach and Operative Technic

A list of the surgical instruments and materials used in the operative procedure is given in Table 1.

The skin incision was made on the posterolateral aspect of the elbow beginning at the distal third of the humerus. The incision was extended distally, passing posterior to the lateral epicondyle and anterior to the olecranon process, and continued distally to the proximal third of the ulna (Plates 3 and 4).

The skin, superficial fascia, and deep fascia were dissected free, exposing the olecranon process, the insertion of the triceps brachii and tensor fasciae antibrachii muscles, and the lateral and medial condyles of the humerus.

The ulnar nerve was located and identified. It crosses the elbow joint posterior to the medial epicondyle. In some cases, the nerve was displaced and/or embedded in traumatized tissues. Therefore, care was exercised in approaching the nerve. The median nerve, crossing the articulation anterior to the medial condyle, lies out of the operative field.

The ulnar nerve was freed along its posterior margin, from the medial epicondyle distally to the biceps brachii muscle proximally. The anterior border of the medial head of the triceps muscle lies under the ulnar nerve. The medial head was freed from the medial and posterior surfaces of the humerus, extending from the olecranon process distally to the biceps brachii muscle proximally.

From the medial surface of the elbow, the tendon of the triceps was undermined by blunt dissection. The dissection was continued through the fascia between the lateral head of the triceps muscle and anconeus and brachialis muscles laterally. On the lateral aspect of the elbow, the anterior border of the lateral head of the triceps was freed from the anconeus and brachialis muscles. The lateral head was freed from the anconeus muscle and posterior surface of the humerus. All four heads of the triceps and tensor fasciae antibrachii muscles were freed distally, along the pos-

terior surface of the humerus, to the olecranon process of the ulna (Plate 5).

A hole was drilled through the olecranon process into the medullary canal of the ulna to a depth sufficient for insertion of a bone screw (Plate 6). This permitted perfect replacement of the olecranon process and a rapid closure. In large breeds, two screws can be inserted parallel to each other for rigid immobilization.

The olecranon process was transected with a Gigli or bone saw (Plate 7), leaving sufficient bone attached to the triceps tendon for firm anchorage on closure (Plate 7 inset).

The transected olecranon process, the tensor fasciae antibrachii muscle, and all four heads of the triceps muscle were reflected proximally as a unit (Plate 8).

The anconeus muscle obscures the joint capsule. Its origin is on the lateral and medial supracondylar ridges of the humerus and the insertion is on the lateral surface of the ulna. By freeing its attachment from the medial supracondylar ridge and reflecting the muscle laterally, the posterior aspect of the joint capsule was exposed. As a result of trauma, this muscle was frequently torn from its attachments and dissection was not required.

The olecranon ligament, extending from the lateral surface of the olecranon process to the medial surface of the lateral condyle, was usually torn when the fracture or dislocation occurred. This ligament is unimportant and its repair was not considered necessary upon closure.

By opening the joint capsule and flexing the elbow, the posterior articular surfaces could be seen (Plate 9). The joint capsule, usually torn as a result of the displacement of the bones, was dissected away to expose the articular surfaces or the intervening soft tissues which were to be removed.

When the articular surfaces were exposed in the experimental animals, lateral condyle, T, or Y fractures were produced. This was accomplished by use of an osteotome and an orthopedic hammer. By this means it was possible to produce the desired type of fracture.

At this point, reduction of dislocations and fractures (Plate 10) was readily accomplished by leverage and manipulation. Temporary immobilization was essential while drilling transversely through the condyles and inserting the intercondyloid bone screw. This can be effected by use of a condyle clamp (Plate 11). However, experience proved that two pairs of vulsellum forceps clamped transversely across the condyles permitted better alignment of the articular surfaces than did the condyle clamp. In addition, these pronged forceps prevented rotation of the fractured condyle(s) while installing the screw. With these forceps there was better visualization and less physical obstruction of the surgical field. In intercondyloid T or Y fractures an intramedullary pin was inserted through the greater tubercle, the shaft of the humerus, and into the medial condyle before closure.

Closure was effected by reattaching the olecranon

process to the ulna by means of a bone screw (Plate 12) or, early in the project, with wire sutures. The lateral and medial heads of the triceps were laid in place and sutured to the adjacent fascia. The skin incision was closed by simple interrupted nylon sutures.

Postoperative Care

The postoperative care of these animals was as follows. The experimental dogs received only minimal care. Daily temperatures were not taken and antibiotics were not used. These animals were kenneled in pairs. Early in the project, Thomas splints were applied to the legs for additional immobilization and support. This procedure was soon discarded since it was found to be unnecessary.

Daily temperatures were taken and antibiotics were routinely used for several days following surgery on the clinic dogs. These dogs were kept in individual kennels. Thomas splints were not used and early restricted use of the injured limb was encouraged.

To aid in making the diagnosis and reaching a prognosis, and to later aid the surgical team, radiographs were taken of the injured elbows of all clinic cases at the time of presentation. Both anteroposterior and lateral radiographs were taken. The experimental animals were not radiographed prior to surgery since these limbs were considered to be normal.

Immediately following surgery, anteroposterior and lateral radiographs were taken of the repaired elbows of all experimental and clinic animals. Radiographs were taken at

this time because: 1) they would show if near perfect realignment of the bone fragments had been achieved or if the dislocation had been reduced; 2) they would reveal if the internal fixation had been properly inserted; and 3) they could be compared with subsequent radiographs to check on the healing process.

Additional radiographs were taken during and/or after completion of the healing process of all experimental animals and of as many of the clinic animals as possible. Since several of the latter dogs were from distant points in Michigan and one was from out-of-state, it was not possible to complete the radiographic series on all these animals. In these cases, oral or written reports were received.

RESULTS

Experimental Cases

The trans-olecranon approach was used on the following experimental dogs, to facilitate production and repair of lateral condyle, T, and Y-fractures of the humerus. The fractures in these experimental dogs were similar to those occurring in accident cases. When the osteotome was driven into the articular cartilage and subchondral bone, the condyle split away from the humeral shaft, leaving a roughened irregular fracture surface.

No attempt was made to deliberately traumatize the soft tissues adjacent to the elbow. If the approach proved to have merit, it was to be used in the repair of accident-induced elbow fractures, particularly those resistant to conservative treatment. Therefore, it was considered unnecessary to simulate the soft tissue trauma as seen in accident-induced injuries.

Dog #1 - Mongrel, male, about one year old, plates 13A-D, pages 54-57.

This dog served as a control to study the effects of surgery, involved in the trans-olecranon approach, on the function of the elbow. The olecranon process was transected, the joint capsule opened, and the articular surfaces examined; the olecranon was then reattached and the skin incision closed.

Two months postoperatively, there had been no loss of function or range of movement of the elbow. There was no evidence of lameness or pain when the leg was used.

Dog #2 - Mongrel, female, approximately one year old.

Left Elbow - plates 14A-D, pages 58-61. A fracture of the lateral condyle was produced. The fracture was reduced and a bone screw inserted. Nine and one-half months following surgery, only about fifty percent of the normal range of movement remained. Although the articular surfaces were in good apposition, the lateral condyle was rotated posteriorly. As a result, the olecranon fossa filled with a bony callus, preventing full extension of the elbow. Due to the torque resulting from the insertion of the intercondyloid screw, the condyle rotated posteriorly. Since a condyle clamp had been used and it did not completely immobilize the condyle, this device was not used in subsequent operations. Two pair of vulsellum forceps were utilized in all the following operations to immobilize the condyles.

Right Elbow - plates 15A-D, pages 62-65. Five months after the surgery on the left elbow, a Y-fracture of the right elbow was induced. Since this elbow was to serve as an untreated control fracture, no repair or immobilization of the elbow was attempted. The olecranon processes was reattached and the skin incision closed. Four and one-half months later, there was complete ankylosis of the elbow. There was marked deformity of both condyles and the articular surfaces. No pain was evidenced when forced manipulation of the elbow was attempted.

Dog #3 - Terrier-type mongrel, female, about eighteen months old, plates 16A-D, pages 66-69.

A Y-fracture of the left humerus was produced. The intercondyloid fracture was reduced and a bone screw inserted. Attempts to insert an intramedullary pin through the greater tubercle of the humerus and into the medial condyle were unsuccessful. The fracture surface of the medial condyle was nearly parallel to the line of approach of the intramedullary pin. An intramedullary pin was inserted through the cortex on the lateral aspect of the distal third of the humerus and into the medial condyle. Four and one-half months later, the dog had nearly normal functional use of the elbow with only slight loss of full extension.

Dog #4 - Cocker-type, female, approximately one year old.

Left Elbow - plates 17A-D, pages 70-73. A Y-fracture of the humerus was induced. The medial condyle was immobilized by insertion of an intramedullary pin from the greater tubercle into the medial condyle. The fracture surfaces of the lateral condyle were such that, following realignment of the condyles, no additional immobilization seemed necessary and an intercondyloid bone screw was not used. Seven and one-half months following surgery, the dog had full functional use of the elbow.

Right Elbow - plates 18A-D, pages 74-77. Two months after the left elbow was fractured and repaired, a T-fracture of the right elbow was produced. Immobilization was obtained by use of a bone screw and intramedullary pin. Five and one-half months postoperatively, the dog had excellent functional use of the elbow. The transected olecranon

process and ulna failed to form a bony union. It was felt the non-union resulted from the failure of the wire sutures used to completely immobilize the transected process.

Dog #5 - Mixed breed, female, about one year old.

Left Elbow - plates 19A-D, pages 78-81. A fracture of the lateral condyle of the humerus was produced. Following reduction, immobilization was achieved by means of a transverse intercondyloid bone screw. Fifteen months postoperatively, the dog had full normal functional use of the limb.

Right Elbow - plates 20A-D, pages 82-85. Four and one-half months after fracturing and repairing the left elbow, a Y-fracture of the right humerus was produced. Following reduction, a bone screw and intramedullary pin were used to obtain immobilization of the bone fragments. Ten and one-half months following surgery, functional results were excellent and the dog had full normal range of movement of the elbow. A non-union developed between the transected olecranon process and ulna. In this case also, it was felt that the wire sutures failed to adequately immobilize the transected bone.

Clinic Cases

The majority of the clinic cases repaired by means of the trans-olecranon approach were considered to be refractory to more conservative surgical procedures. Because of this, treatment of these difficult cases was undertaken to prove the merits of this approach and operative technic and to restore as much function as possible to these elbows.

The following cases were operated by one or more members of the small animal clinic staff with direct physical assistance by the author.

Case #34303 - Brittany Spaniel, male, six months old, plates 21A-D, pages 86-89.

At the time of presentation the dog had been limping for three weeks. A fracture of the left lateral humeral condyle was diagnosed. There was no history of prior treatment. Due to callus formation only limited movement of the elbow remained. The posterior approach was performed. The interfering callus was removed, the fracture reduced, and internal fixation applied. Eight months following surgery, the functional results were excellent, with no indication of lameness.

Case #34437 - Brittany Spaniel, spayed female, six years old, plates 22A-D, pages 90-93.

The dog was presented with a history of an untreated lameness of two months duration. A lateral condyle fracture of the right humerus was diagnosed. The dog was limping and evidenced pain in the leg. The fractured condyle had healed to the shaft of the humerus proximal to the supracondylar region. The open approach was performed, the condyle freed from its attachment to the shaft, and the fracture reduced. A bone screw was inserted through the condyles. Six weeks postoperatively, the dog favored the leg only following strenuous exercise.

Case #36082 - English Bulldog, male, one and one-half years old, plates 23A-D, pages 94-97.

A fracture of the lateral condyle of the left humerus of four days duration was diagnosed. A limited surgical approach was performed. Attempted reduction was unsuccessful. Muscle conracture and interposing muscle tissues prevented realignment of the condyles. The trans-olecranon approach was used, the intervening soft tissues removed, and internal fixation applied. Twelve days after surgery the dog was bearing weight on the limb. A later report was unavailable at the time this paper was written.

Case #36809 - Cocker Spaniel, male, two years old, plates 24A-D, pages 98-101.

A lameness of five days duration was diagnosed as a fracture of the left medial humeral condyle. Soft tissue callus prevented manipulation of the fragment. Closed reduction was impossible and a limited surgical approach was considered inadequate. The posterior approach permitted removal of the callus, realignment of the articular surfaces, and facilitated insertion of a bone screw. Six weeks postoperatively, there was excellent functional use of the leg, with no indication of any lameness.

Case #35222 - German Shephard, male, three years old, plates 25A-D, pages 102-105.

A Y-fracture of the right humerus which occurred three days prior to presentation was diagnosed. The posterior approach permitted more perfect reduction and easier application of internal fixation. Six months following surgery, there was excellent functional use of the leg. Although the dog walked without a limp, the elbow could not

be fully extended.

Case #35814 - Cocker Spaniel, male, five years old, plates 26A-D, pages 106-109.

A T-fracture of the left elbow of two weeks duration was referred to the clinic for treatment. Prior to presentation a modified Thomas splint had been applied but had failed to maintain satisfactory reduction. At the time of presentation, swelling, crepitation, and pain were noted in the elbow. Extensive fibrin clots and organized tissues were removed prior to reduction and application of internal fixation. The trans-olecranon approach facilitated the repair. One month following correction and discharge of the patient, gradual use of the leg was returning. Unfortunately, the lateral condyle of the right humerus was fractured when the dog caught its leg in a chain.

Case #35299 - Collie, male, five and one-half years old, plates 27A-D, pages 110-113.

An untreated lateral dislocation of the right elbow of three weeks duration was referred to the clinic for correction. Creptitation, lameness, and pain were exhibited in the elbow. Attempted manual reduction was unsuccessful. The trans-olecranon approach was performed and the obstructing callus removed, permitting reduction of the dislocation. Three months postoperatively, the dog had only a slight limp.

In the majority of the cases listed below, which were operated by staff clinicians, the author was in attendance in an advisory capacity.

Case #33050 - English Bulldog, male, six months old, plates 28A-C, pages 114-116.

A fracture of the lateral condyle of the right humerus of four weeks duration was dignosed. There was no history of previous treatment. The posterior approach was used, the organized tissue callus was removed, and internal fixation was inserted. At the time of discharge, ten days after surgery, gradual use of the leg was returning. A more recent report was unavailable at the time this paper was prepared.

Case #35513 - Brittany Spaniel, male, six years old, plates 29A-D, pages 117-120.

A fracture of the lateral condyle of the left humerus, which had been treated three months previously with a Thomas splint, was referred to the clinic for treatment. On presentation, crepitation, indicated the fracture had failed to healed. Movement was limited and painful. The trans-olecranon approach allowed removal of the obstructing callus and reduction of the fracture. Immobilization was by internal fixation. Three months later, the dog still favored the leg but showed continued improvement.

Case #36160 - Manchester Terrier, male, four months old, plates 30A-D, pages 121-124.

A fracture of the left lateral humeral condyle of ten days duration was diagnosed. Previously treated as a simple sprain. Because of failure to respond to treatment, it was referred for radiographs. The trans-olecranon approach was used, the obstructing callus removed, the fracture reduced, and a bone screw inserted. A fully threaded

intramedullary pin was used to immobilize the transected olecranon process. The small size of the ulna would not permit use of a bone screw. Two months postoperatively, there was excellent functional use of the leg. There was no lameness and no loss of range of movement.

Case #3189 - Cocker Spaniel, male, ten years old, plates 31A-D, pages 125-128.

A Y-fracture of the left humerus was operated the same day as the injury occurred. The posterior approach permitted accurate realignment of the articular surfaces. A bone screw and intramedullary pin were used to immobilize the bone fragments. Radiographs taken two weeks following surgery revealed the fracture to be slowly healing. Three months postoperatively, the dog used the leg fully and without hesitation, though there is restriction in movement of the joint. In addition, there was a slight limp.

Case #31909 - Boxer, male, one year old, plates 32A-G, pages 129-135.

A one day old fracture of the lateral condyle of the left humerus was diagnosed. The fracture was reduced using a limited surgical approach. Ten days later the bone screw, used to immobilize the fracture, broke. The posterior approach facilitated removal of the broken screw and insertion of a new screw.

DISCUSSION

In an attempt to produce a dry surgical field, the legs of the first two experimental dogs were tightly wrapped with an elastic bandage from the toes to well above the elbow. A rubber tourniquet was applied above the bandage, the bandage removed, and the leg prepared for surgery. This technic failed to eliminate hemorrhage from the transected olecranon process or the fractured bones. Since the soft tissue dissection was along fascial planes and through naturally occurring muscle separations, very few blood vessels were encountered. As a result, when the use of the tourniquet was discontinued in subsequent operations, only slight additional capillary hemorrhage resulted.

Reference was made earlier to the use of Thomas splints to immobilize the operated limbs. Besides being unnecessary and probably contraindicated, the proper application of these splints requires skill, consumes time, and necessitates numerous re-examinations and adjustments. After discontinuing the use of these splints, frequently, within a week to ten days following surgery, extension and flexion of the injured elbows began to return. In addition, the dogs were bearing weight on these limbs.

Of the twenty operated and repaired elbows reported in this paper, the transected olecranon process was reat-

tached to the ulna by wire in ten cases, by a threaded intramedullary pin in one case, and by bone screws in nine cases.

In those elbows in which wire had been used, eight were in experimental dogs. Bony union between the transected process and the ulna failed to develop in two of the experimental dogs. In a majority of the remaining experimental dogs, a deformed olecranon process resulted. Failure to achieve complete immobilization of the transected process was the probable cause of these poor results.

A small diameter fully threaded intramedullary pin was used to immobilize the transected process in a four month old Manchester Terrier. The ulna and transected process were too small and fragile to use wire or a bone screw. Excellent immobilization and healing was obtained using this type of fixation.

In the nine cases where bone screws were used, healing progressed at a normal rate and terminated in an anatomically near perfect olecranon process. The use of predrilled holes and bone screws in the repair of the transected olecranon process has these advantages: 1) more rapid closure is permitted; 2) near perfect apposition of the bone fragments is obtained; 3) complete immobilization of the process is achieved; 4) the immobilization is more positive and stronger than that attained by either wire sutures or non-threaded intramedullary pins; 5) because the fixation is more certain, no external splinting is needed; (6) the convalescence period is shortened; and (7) since the joint is not immobilized, ankylosis is less likely to develop.

Advantages of the trans-olecranon approach are: 1) ease of the approach; 2) attainment of maximum exposure; 3) perfect reduction of the bone fragments is permitted; and 4) application of internal fixation is facilitated. These conclusions are based in part on the fact that the majority of the clinic cases operated by this approach were considered inoperable using more conservative surgical approaches or, based on previous experience, had surgery been attempted the end results would have been less satisfactory. Function, even though not complete in all cases, was restored to otherwise nonfunctional elbows. In view of this, the results obtained must be regarded as most satisfactory.

Fundamentals to be observed in treating injuries involving joints are: 1) early reduction and attainment of "hair line" apposition of the bone fragments; 2) uninterrupted immobilization; and 3) freedom of movement of the joint following surgery.

The role on muscle contraction in elbow dislocations and humeral condyle fractures should not be underestimated. Initially, muscle contraction contributes to the displacement of the bones or bone fragments. For example, in humeral intercondyloid T or Y fractures, contraction of the triceps, biceps, and brachialis muscles pulls the olecranon process proximally, wedging the condyles apart. Constant muscle contraction maintains this displacement. If reduction is to be effected, counter traction must be applied to counteract this muscle pull. When counter traction fails, the trans-olecranon approach is invaluable in overcoming contraction

of the triceps brachii muscle. Transection of the olecranon process is in effect the same as severance of the triceps tendons. As a result, reduction of dislocations and fractures of the elbow is greatly facilitated.

Tissue changes following dislocations and fractures involving joints are much the same as those following any traumatic injury. Blood and lymph vessels in the joint capsule, periosteum, medullary canal, and adjacent soft tissues are torn. This produces a hematoma and edema. Within twenty-four hours a fibrous or temporary callus begins to develop. The fibrin network is infiltrated by fibroblasts, angioblasts, osteoblasts, leukocytes, and macrophages. Concurrently and ensuing, injured tissues undergo degeneration, necrosis, and reabsorption. Superficial decalcification of all viable bone fragments takes place. Following this there is formation of the primary bone callus. As these changes progress, successful reduction becomes increasingly difficult with each day of delay.

Dislocations can usually be reduced by ordinary manipulative procedures within the first five to ten days following injury. After this period of time, tissue changes make closed reduction a physical impossibility. In these cases, more radical procedures are indicated if reduction is to be achieved. An open approach with removal of the fibrous callus or primary bone callus is essential. In most cases debridement can best be accomplished by use of forceps, scissors, osteotomes, and bone rongeurs. Following removal of this tissue, reduction is attained by a combination of

leverage and manipulation. Early movement is desired and should be encouraged if maximum functional results are to be realized. Therefore, external splinting is seldom recommended.

Occasionally, in a simple condyle fracture of recent origin, soft tissues may be interposed between the bone fragments preventing successful closed reduction by closed manipulation or by the usual operative procedures. In long-standing fractures callus formation usually prevents reduction by ordinary operative methods. In such cases, the trans-olecranon approach makes it possible to remove the obstructing soft tissues, fibrin clots, or tissue callus. In addition, it facilitates the realignment of the bone fragments and application of rigid internal fixation. Normally no external fixation is used. Early restricted movement of the elbow is ideal.

It is felt that the trans-olecranon approach is the treatment of choice for repair of nearly all T and Y fractures of the humerus, because the best possible exposure and reduction can be obtained.

Infrequently, due to abnormal stress or failure to properly restrict the exercise of a patient, a bone screw may break before healing has reached the point of clinical union. Here the trans-olecranon approach is most useful in removing the broken pieces and applying new internal fixation.

Recent dislocations and uncomplicated condyle fractures are best treated by conventional methods, ie., closed

reduction or lateral or medial surgical approaches. In the event these procedures fail and in order to prevent additional and unnecessary tissue trauma, the trans-olecranon approach should be used to effect reduction. Complicated recent lateral or medial condyle fractures and old irreducible dislocations and fractures are best corrected by this posterior approach. This approach is indicated in nearly all intercondyloid T and Y fractures of the humerus.

SUMMARY

1. A posterior open approach to the canine elbow is described. Briefly, this approach consists of transecting the olecranon process and reflecting it and its muscle attachments proximally.

2. Utilizing this approach, condyle fractures were produced and then repaired in experimental dogs.

3. Following the development and refinement of the surgical approach and operative procedure, twelve accident-induced dislocated and fractured elbows were repaired using this approach and technic.

4. The results obtained thus far are as good as, or superior to, those obtained by more conservative treatment of similar type elbow injuries.

5. The use of vulsellum forceps to immobilize fractured condyles while drilling through and inserting a bone screw into the condyles is described.

6. The superiority of bone screws over wire sutures, to immobilize transected olecranon processes, is discussed.

7. The use of Thomas splints to immobilize the repaired elbow is unnecessary and may be contraindicated in most cases. Early restricted use of the elbow is discussed.

8. Indications for use of this approach are: a) dislocations of the elbow which cannot be reduced by ordinary

procedures; b) fractures of the elbow, either recent or old, which cannot be adequately reduced by more conservative procedures; and c) removal of broken internal fixation and replacement with new internal fixation.

TABLE 1

SURGICAL INSTRUMENTS AND MATERIALS
USED IN OPERATIVE PROCEDURE

The glove pack contained:

Two pairs of rubber surgical gloves

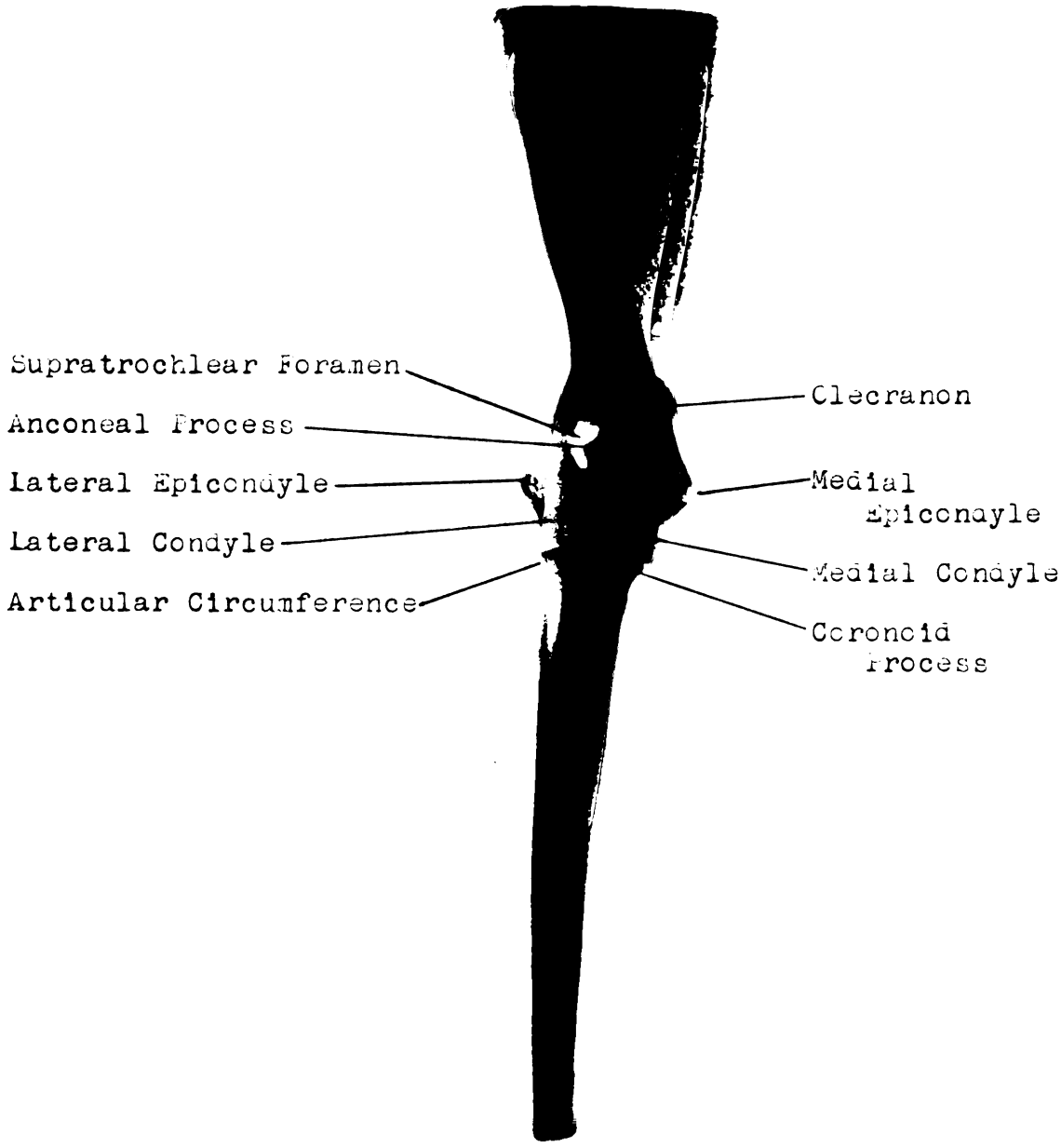
The general surgical pack contained:

Two hand towels
Two surgical gowns
Two drapes
One scapel blade
One scapel handle
One pair surgical scissors
Four towel clamps
Four hemostats
Two Allis tissue forceps
Numerous gauze surgical sponges

Special bone surgery pack contained:

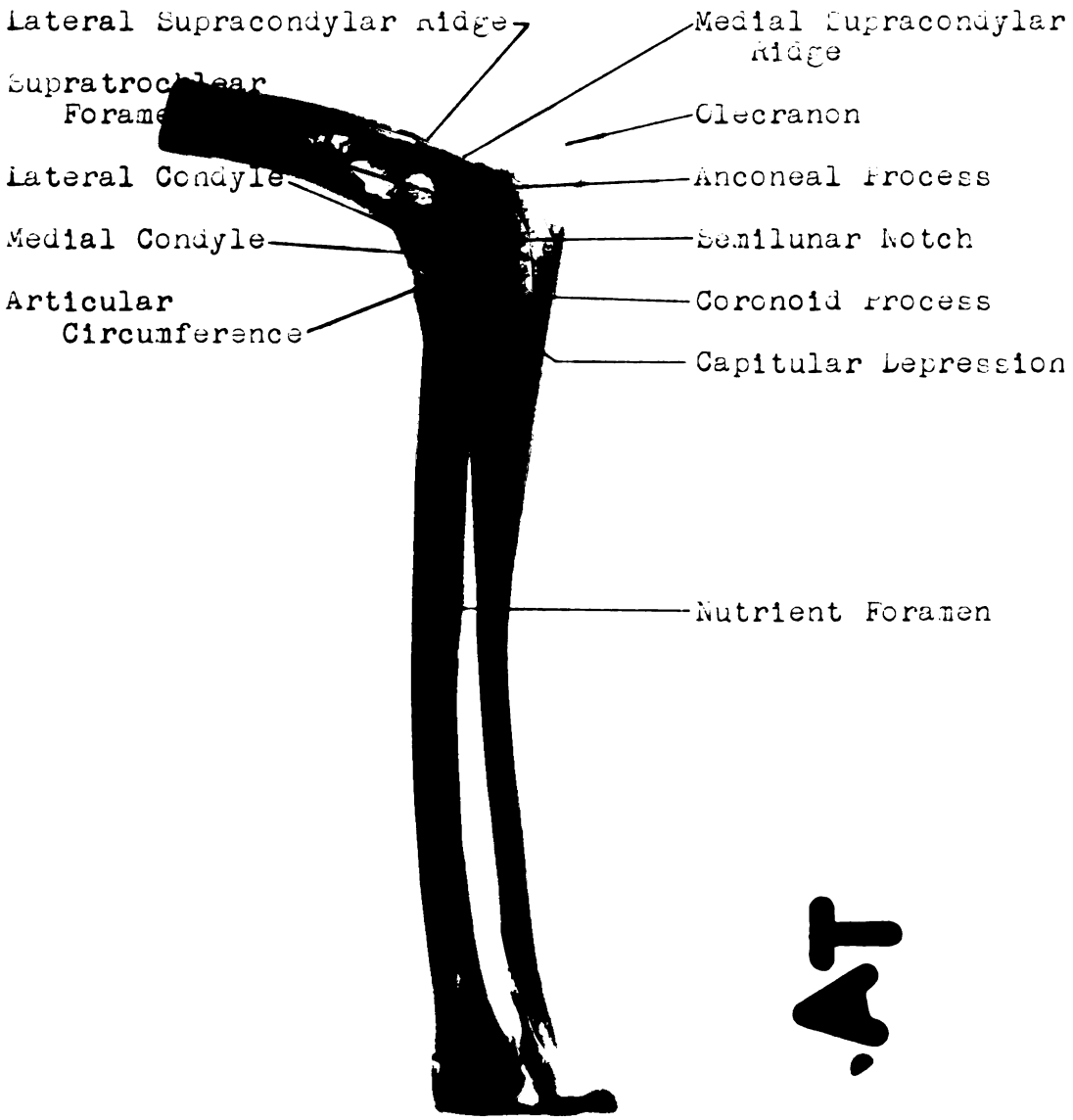
Pin chuck and key
Seven/sixty-fourth inch bone drill
Gigli saw or Satterlee aseptic bone saw
One or more osteotomes
One or more bone rongeurs
Two pair of vulsellum forceps
Lane screw driver
Selection of various length Sherman bone screws
Selection of various length and diameter trocar pointed intramedullary pins
Pin cutter
Extra hand towels, drapes, and gauze surgical sponges
Several straight surgical needles
Several twelve inch lengths of .010" tantalum wire
Stainless steel orthopedic hammer

PLATE 1



Anteroposterior aspect of the right humero-radial-ulnar articulation of a normal adult terrier-type dog.

PLATE 2



Mediolateral aspect of the right humero-radial-ulnar articulations of a normal adult terrier-type dog.

PLATE 3

Lateral aspect of foreleg showing line of skin incision.

PLATE 4

Posterior aspect of foreleg showing posterolateral line of skin incision.

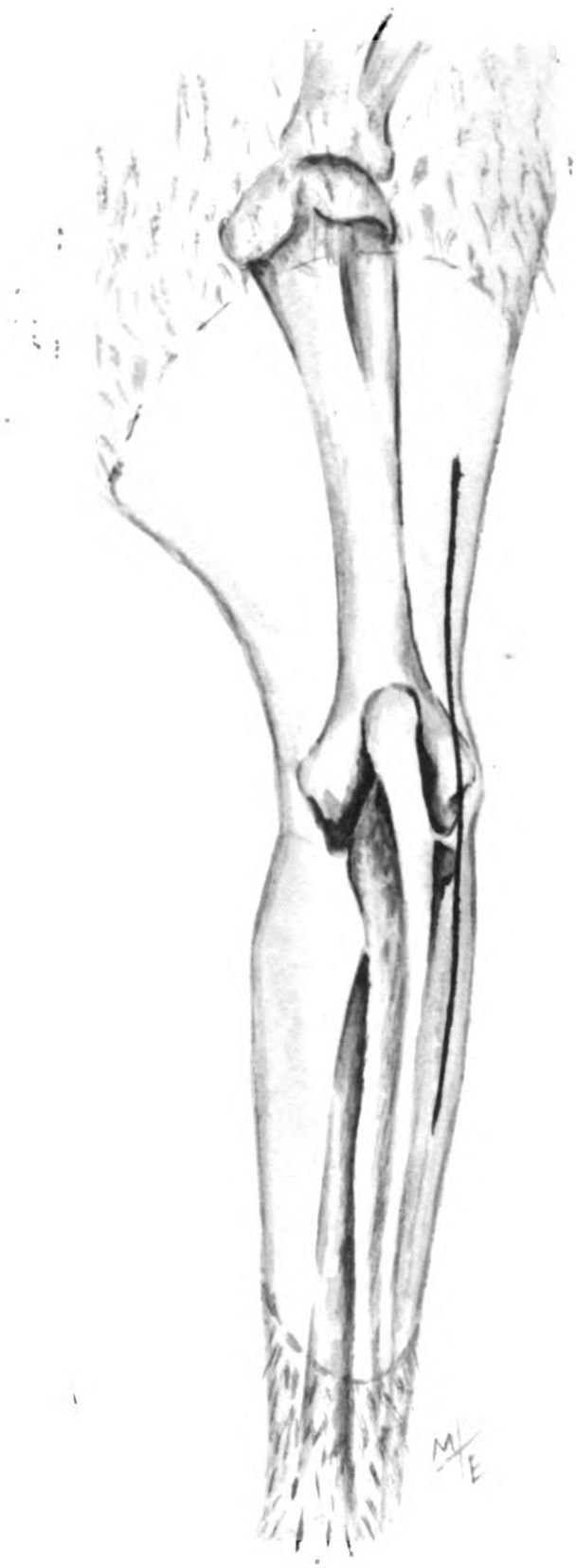


PLATE 5

Separation of tensor fasciae antibrachii and all four heads of the triceps brachii muscle.

PLATE 6

Drilling hole through the olecranon process.

PLATE 7

Transection of olecranon process with a Gigli saw. Inset shows line of transection.

PLATE 8

Olecranon process and muscle insertions reflected proximally, showing anconeus muscle in place and the posteromedial surface of the humerus.

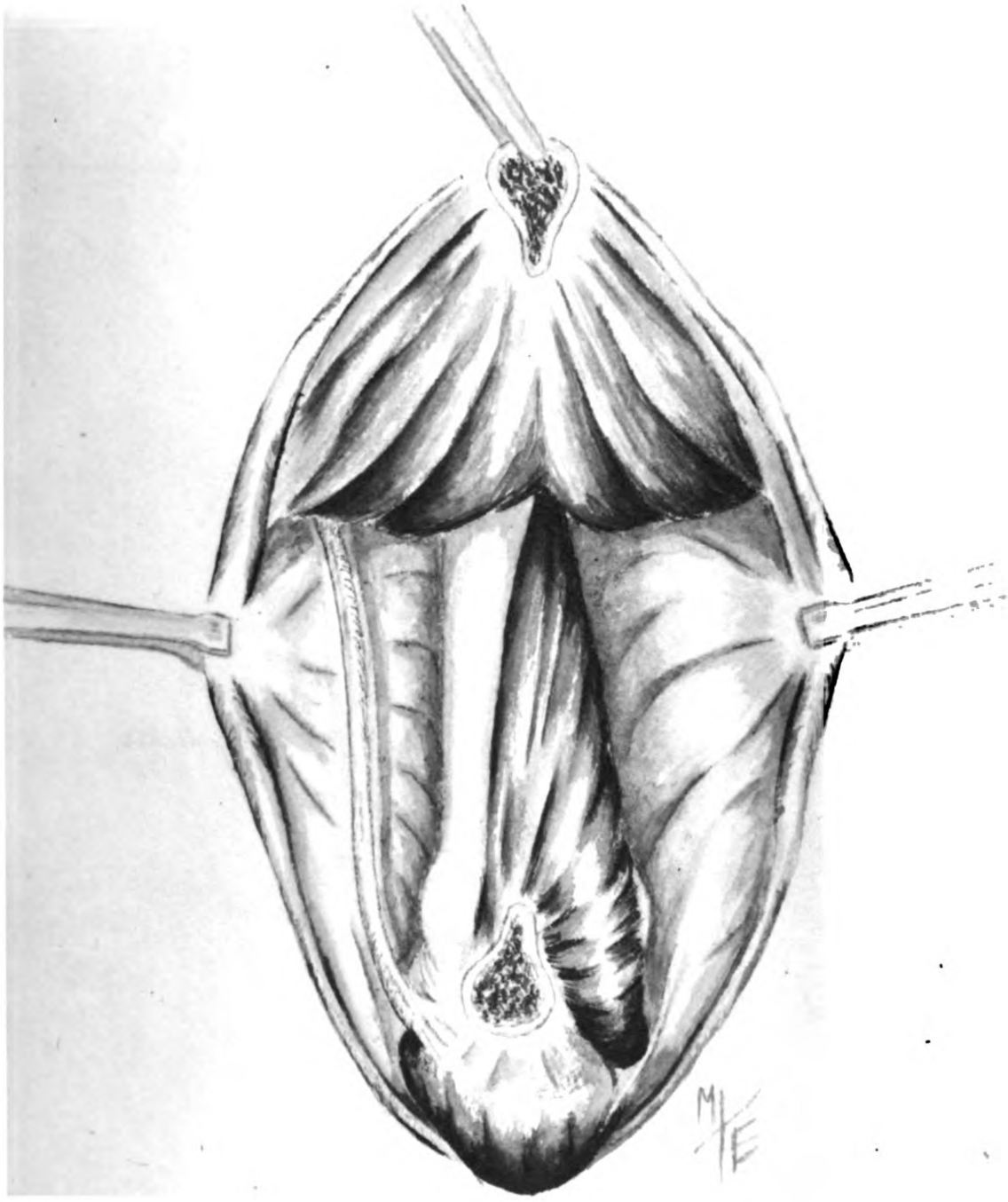

M/E

PLATE 9

Posterior aspect of the elbow joint. The anconeus muscle is reflected laterally and the joint capsule dissected free.

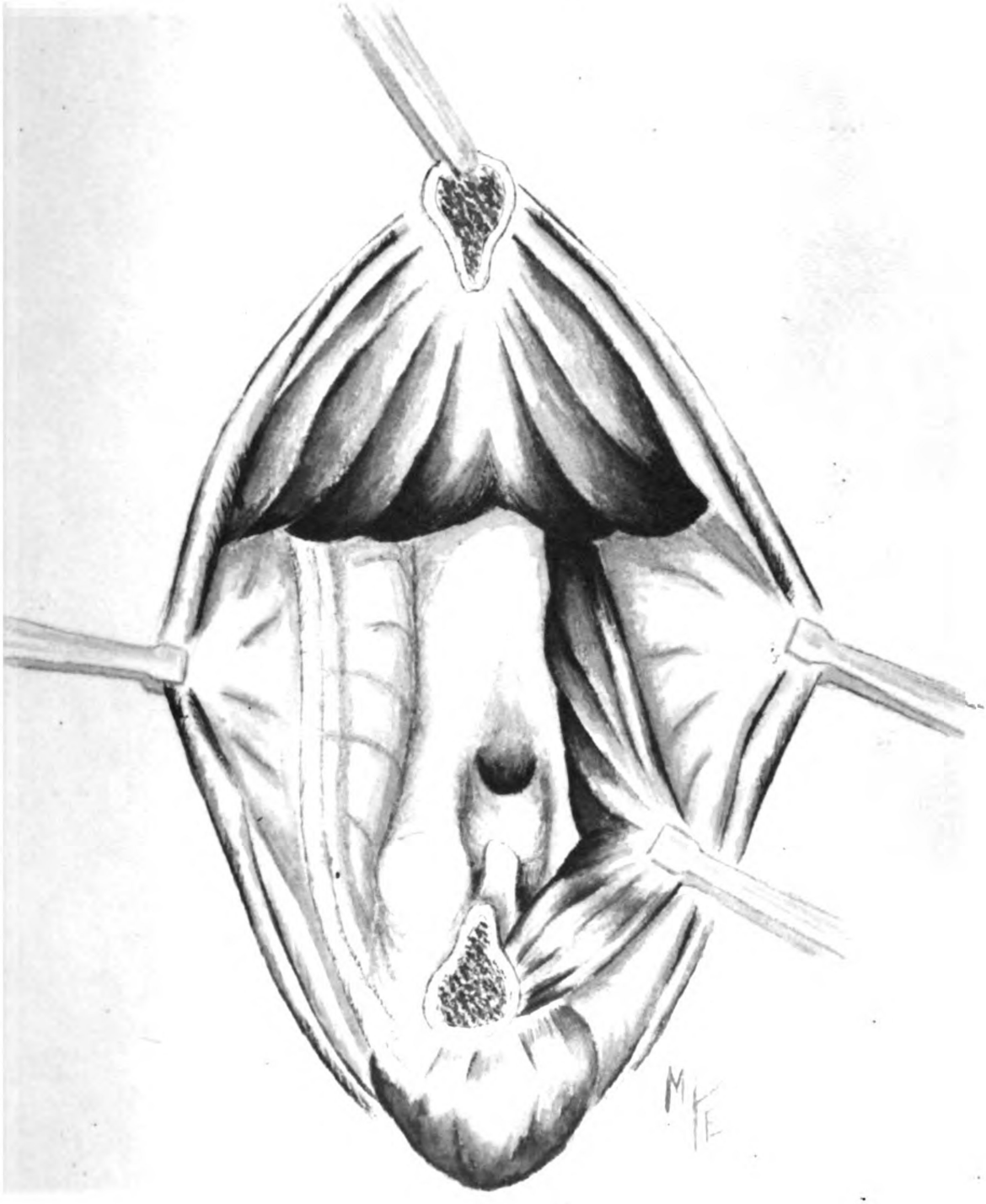


PLATE 10

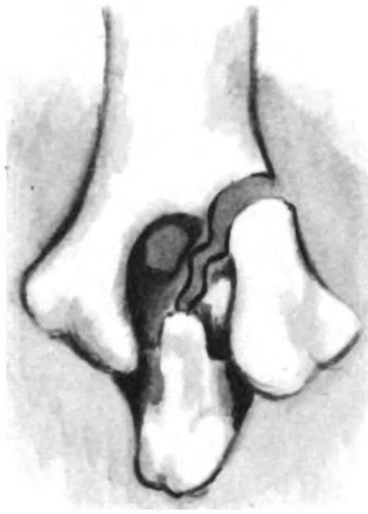
Diagrammatic drawings showing typical fractures of the distal end of the humerus.

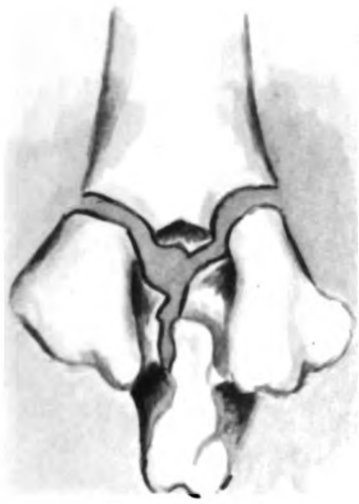
Upper left - a medial condyle fracture.

Upper right - a lateral condyle fracture.

Lower left - a "T" or "Y" fracture.

Lower right - a supracondylar fracture.





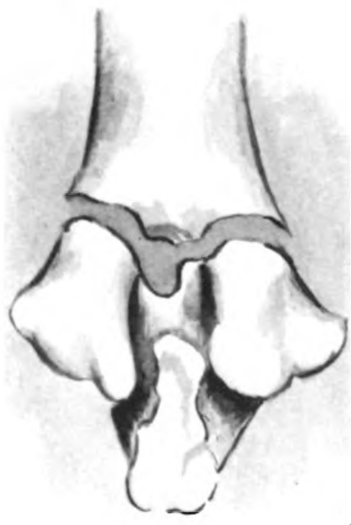


PLATE 11

Posterior and lateral views of the elbow showing a condyle clamp in place.

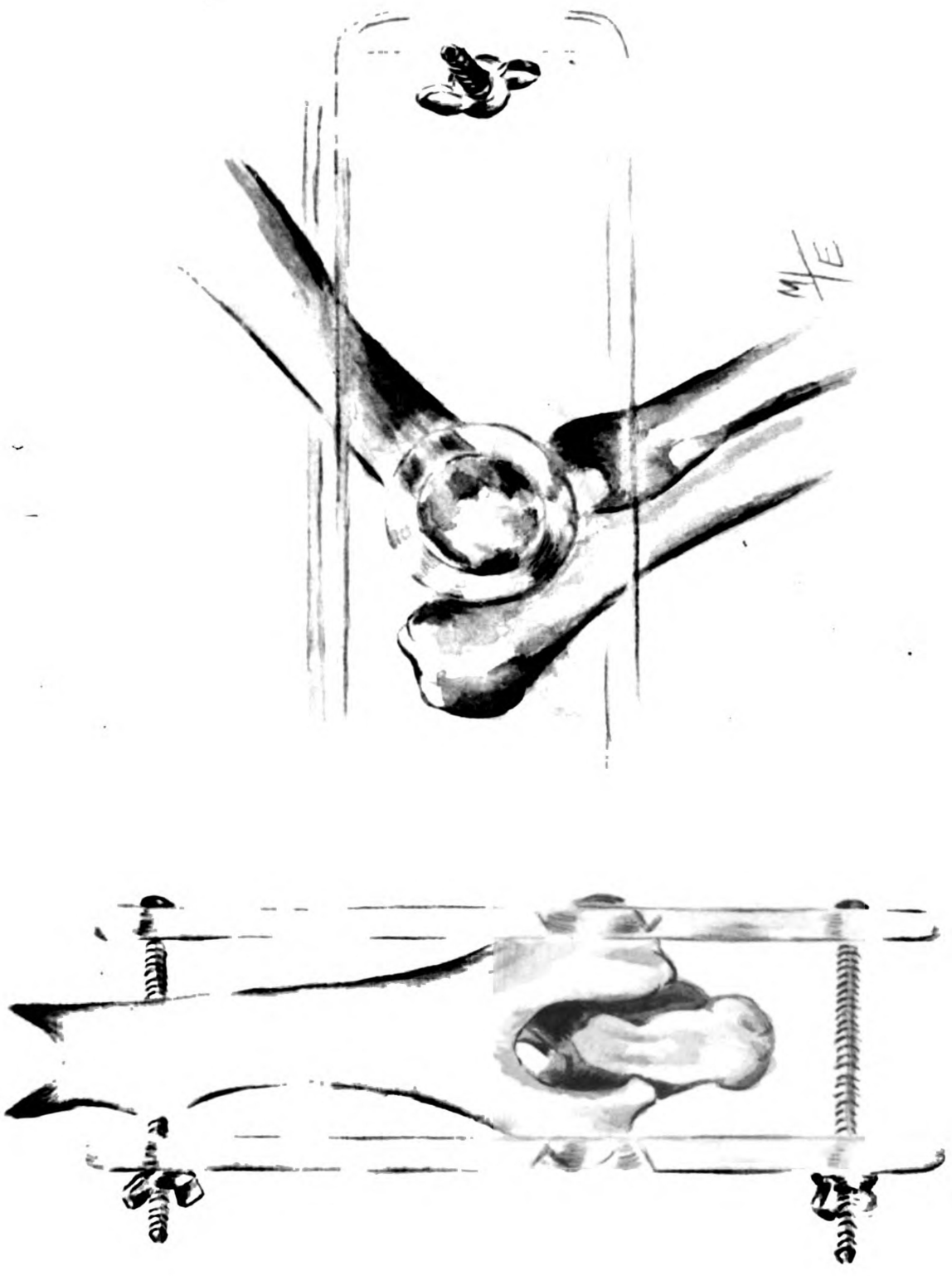


PLATE 12

Insertion of bone screw to reattach and immobilize the transected olecranon process.

PLATES 13A-D

Dog #1 - Mongrel, male, about one year old, see page 24.

This dog served as a control to study the effects of surgery, involved in the transolecranon approach, on the function of the elbow.

Plate 13A, page 54 - anteroposterior aspect of the left elbow three days postoperatively.

Plate 13B, page 55 - mediolateral aspect three days postoperatively.

Plate 13C, page 56 - anteroposterior aspect fifty-one days postoperatively.

Plate 13D, page 57 - mediolateral aspect fifty-one days postoperatively.

PLATE 13A

PLATE 133

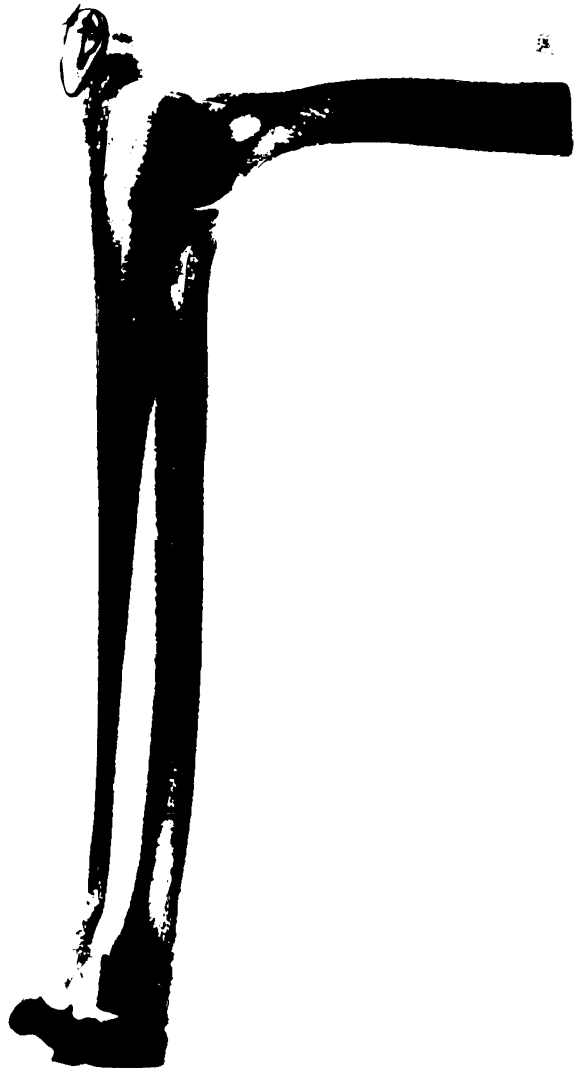


PLATE 13C

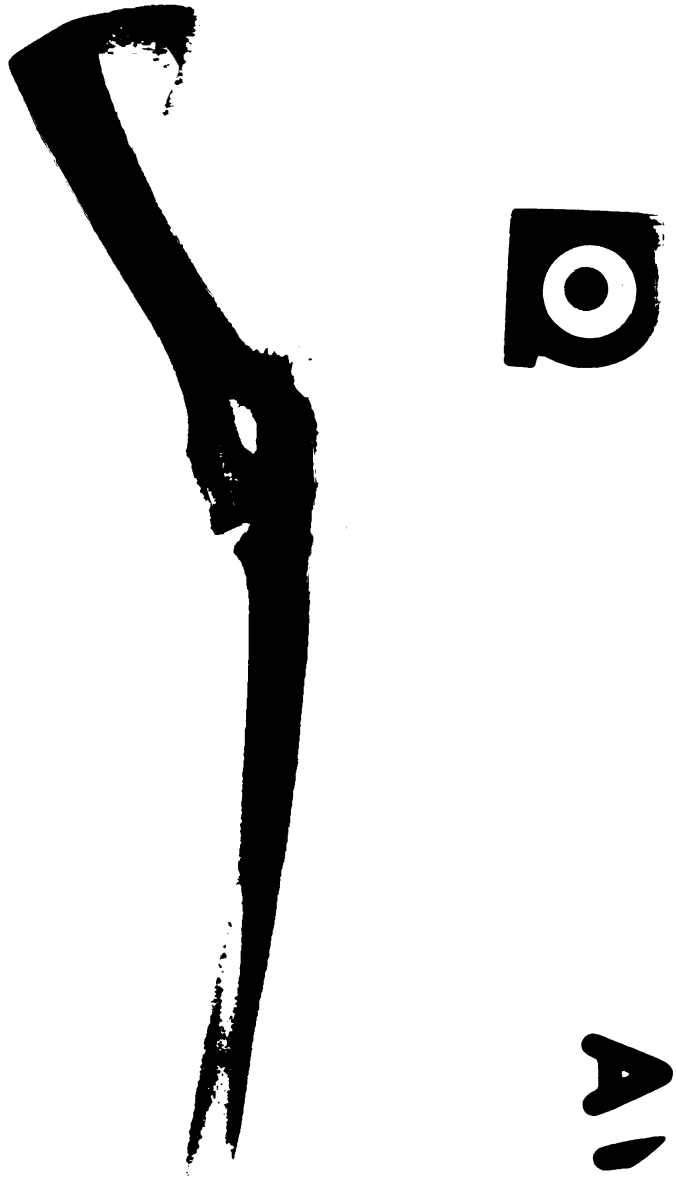
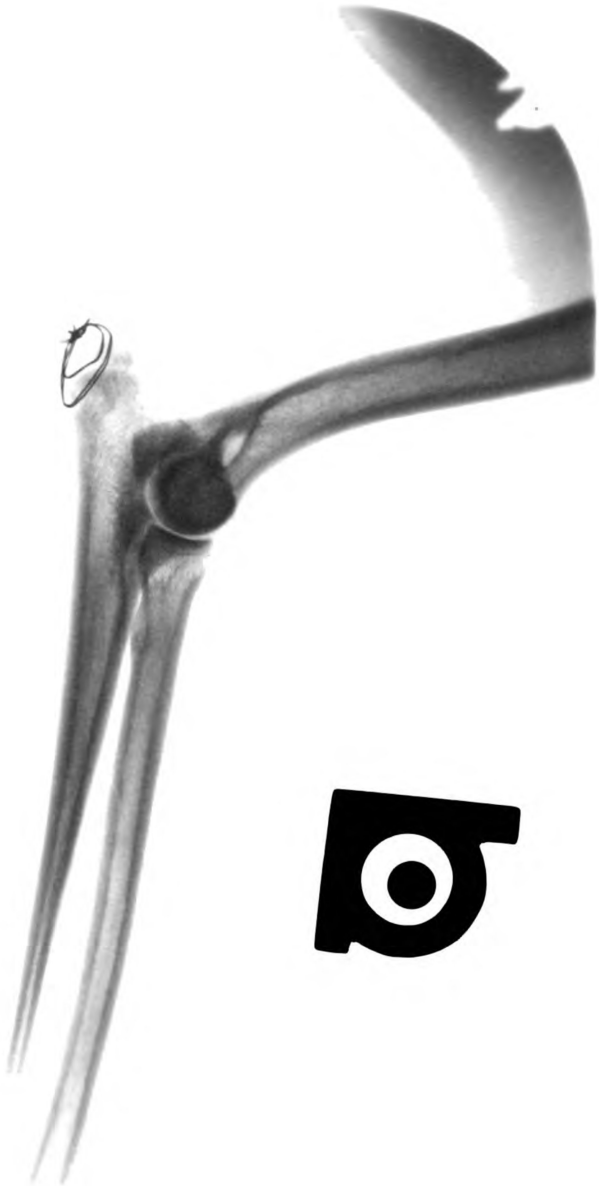


PLATE 13D



PLATES 14A-D

Dog #2 - Mongrel, female, approximately one year old, see page 25.

An induced lateral condyle fracture of the left elbow.

Plate 14A, page 58 - anteroposterior aspect of the elbow following reduction and immobilization.

Plate 14B, page 59 - mediolateral aspect following reduction and immobilization.

Plate 14C, page 60 - anteroposterior aspect nine and one-half months following surgery.

Plate 14D, page 61 - mediolateral aspect nine and one-half months following surgery.

PLATE 14A

PLATE 14B

PLATE 14C

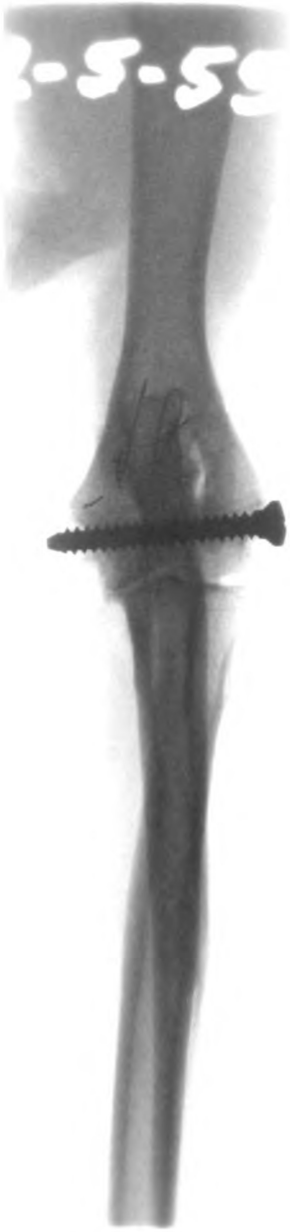


PLATE 14D

PLATES 15A-D

Dog #2 - Mongrel, female, approximately one year old, see page 25.

Five months after surgery on the left elbow, a Y-fracture of the right elbow was produced. Since this elbow was to serve as an untreated control fracture, no repair or immobilization was attempted.

Plate 15A, page 62 - anteroposterior aspect of the elbow following surgery.

Plate 15B, page 63 - mediolateral aspect following surgery.

Plate 15C, page 64 - anteroposterior aspect four and one-half months later showing ankylosis of the elbow.

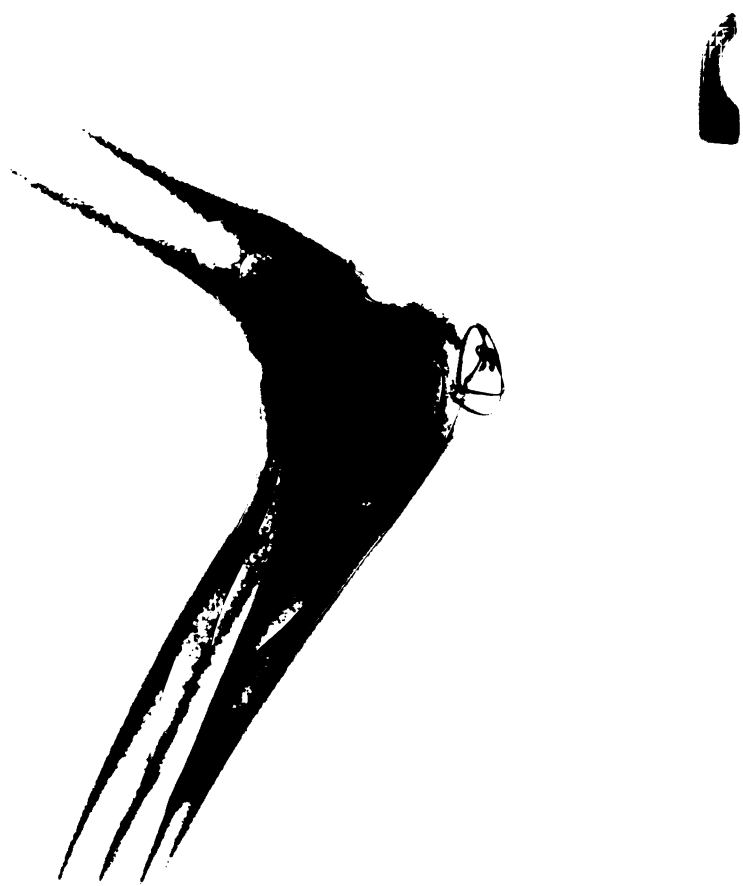
Plate 15D, page 65 - mediolateral aspect four and one-half months later showing ankylosis of the elbow.

PLATE 15A

PLATE 153

PLATE 15C

PLATE 15D



PLATES 16A-D

Dog #3 - Terrier-type mongrel, female, about eighteen months old, see page 26.

A Y-fracture of the left humerus was produced. After reduction and immobilization of the intracondylar fracture, immobilization of the remaining supracondylar fracture was achieved by insertion of an intramedullary pin through the cortex of the lateral aspect of the distal third of the humerus and into the medial condyle.

Plate 16A, page 66 - anteroposterior aspect of the elbow following reduction and immobilization.

Plate 16B, page 67 - mediolateral aspect following reduction and immobilization.

Plate 16C, page 68 - anteroposterior aspect four and one-half months postoperatively.

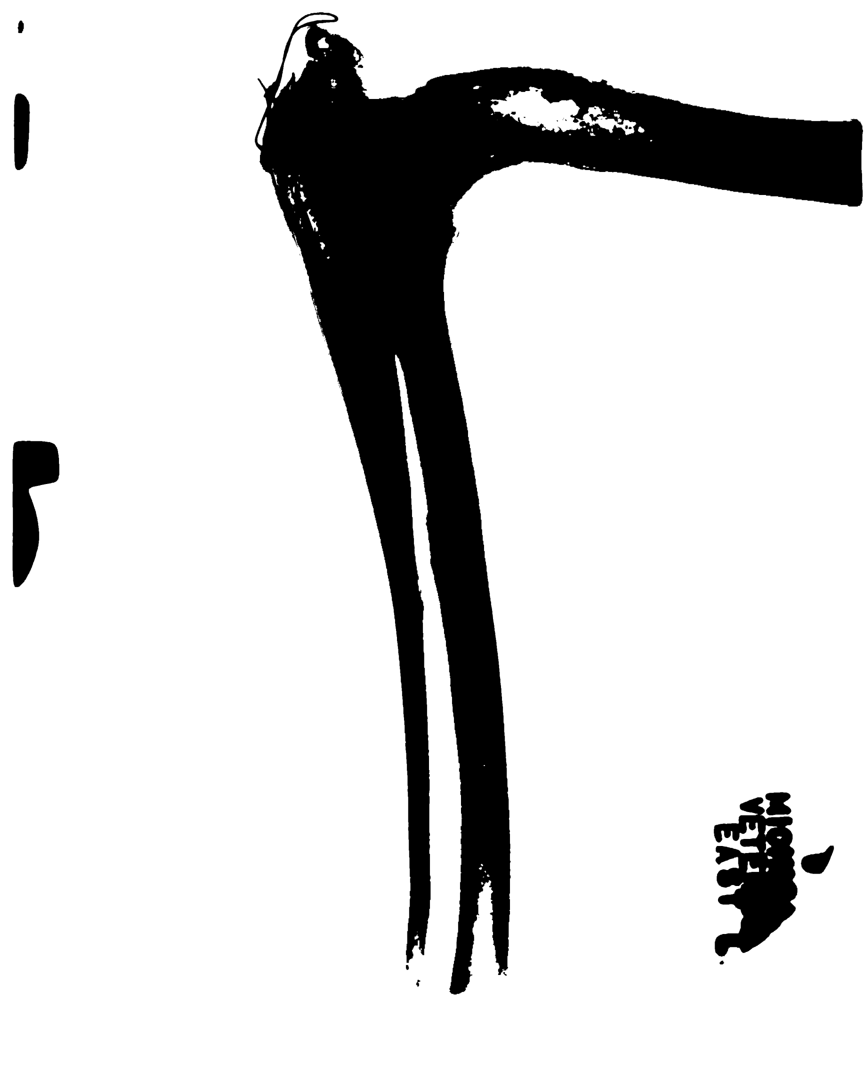
Plate 16D, page 69 - mediolateral aspect four and one-half months postoperatively.

PLATE 16A

PLATE 16B

PLATE 16C

PLATE 16D



PLATES 17A-D

Dog #4 - Cocker-type, female, approximately one year old, see page 26.

A Y-fracture of the left elbow was induced. The medial condyle was immobilized by insertion of an intramedullary pin. The fracture surfaces were such that, following realignment of the condyles, no additional fixation was used.

Plate 17A, page 70 - anteroposterior aspect of the elbow following surgery.

Plate 17B, page 71 - mediolateral aspect following surgery.

Plate 17C, page 72 - anteroposterior aspect seven and one-half months postoperatively.

Plate 17D, page 73 - mediolateral aspect seven and one-half months postoperatively.

PLATE 17A

PLATE 17B

PLATE 17C

PLATE 17b

PLATES 18A-D

Dog #4 - Cocker-type, female, approximately one year old, see page 26.

Two months following surgery on the left elbow, a T-fracture of the right elbow was produced.

Plate 18A, page 74 - anteroposterior aspect of the elbow following fracturing and repair.

Plate 18B, page 75 - mediolateral aspect following fracturing and repair.

Plate 18C, page 76 - anteroposterior aspect five and one-half months following surgery.

Plate 18D, page 77 - mediolateral aspect five and one-half months following surgery. Note non-union of the transected olecranon.

PLATE 18A

PLATE 18B

PLATE 18C

PLATE 18D

PLATES 19A-D

Dog #5 - Mixed breed, female, about one year old, see page 27.

A lateral condyle fracture of the left elbow was produced.

Plate 19A, page 78 - anteroposterior aspect of elbow following reduction and immobilization.

Plate 19B, page 79 - mediolateral aspect following reduction and immobilization.

Plate 19C, page 80 - anteroposterior aspect fifteen months postoperatively.

Plate 19D, page 81 - mediolateral aspect fifteen months postoperatively.

PLATE 19A

PLATE 193

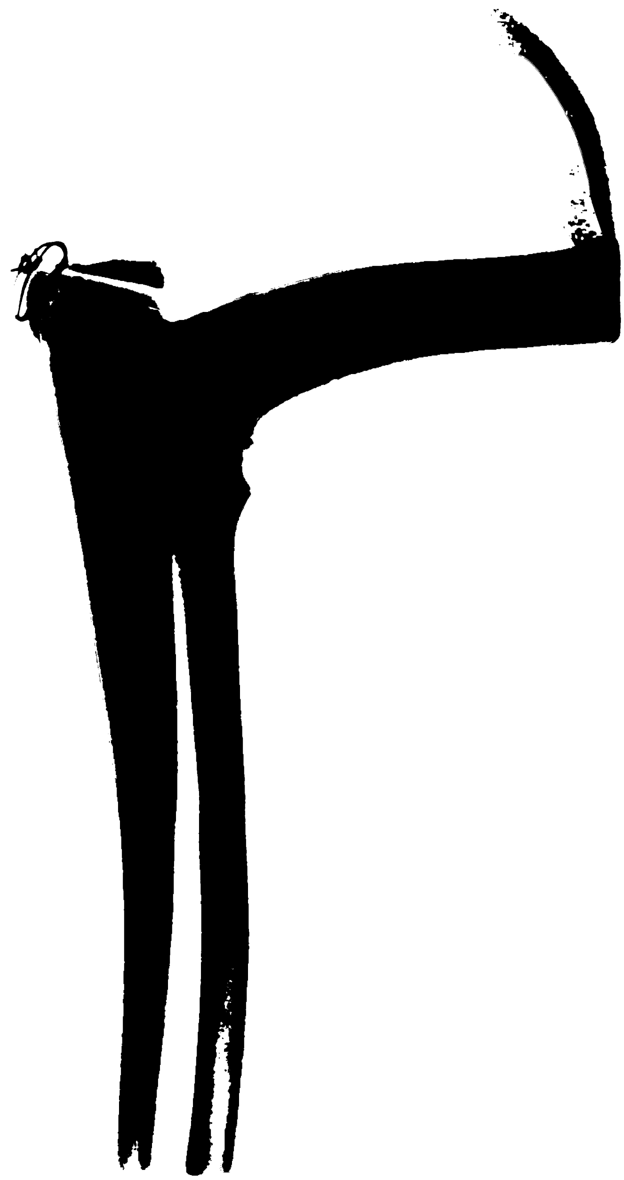


PLATE 19C

AP

PLATE 19B

PLATES 20A-D

Dog #5 - Mixed breed, female, about one year old, see page 27.

Four and one-half months after surgery on the left elbow, a Y-fracture of the right humerus was produced.

Plate 20A, page 82 - anteroposterior aspect of elbow following surgery.

Plate 20B, page 83 - mediolateral aspect following surgery.

Plate 20C, page 84 - anteroposterior aspect ten and one-half months postoperatively.

Plate 20D, page 85 - mediolateral aspect ten and one-half months postoperatively. Note non-union of the transected olecranon.

PLATE 20A

PLATE 20B

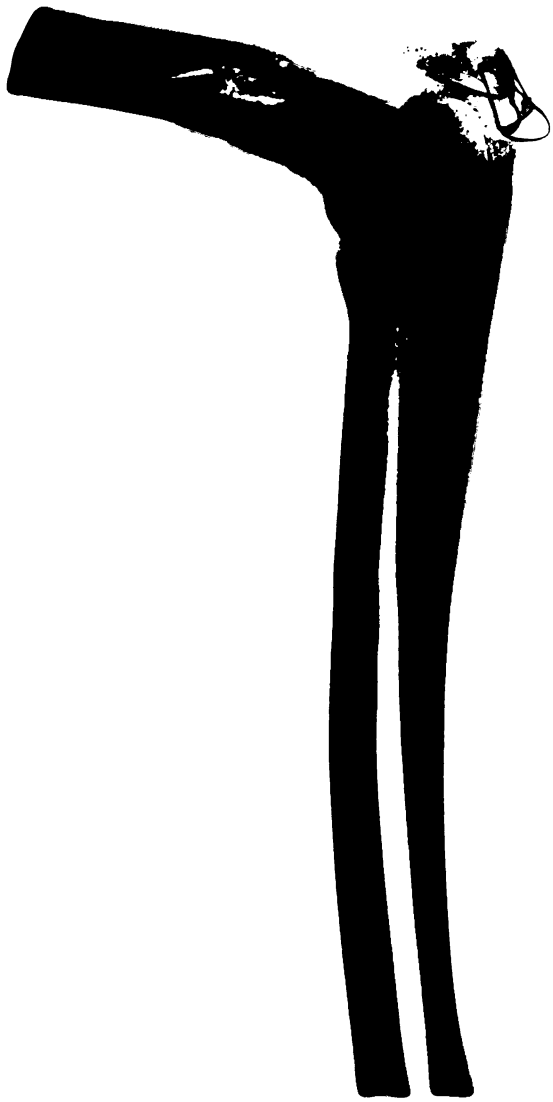


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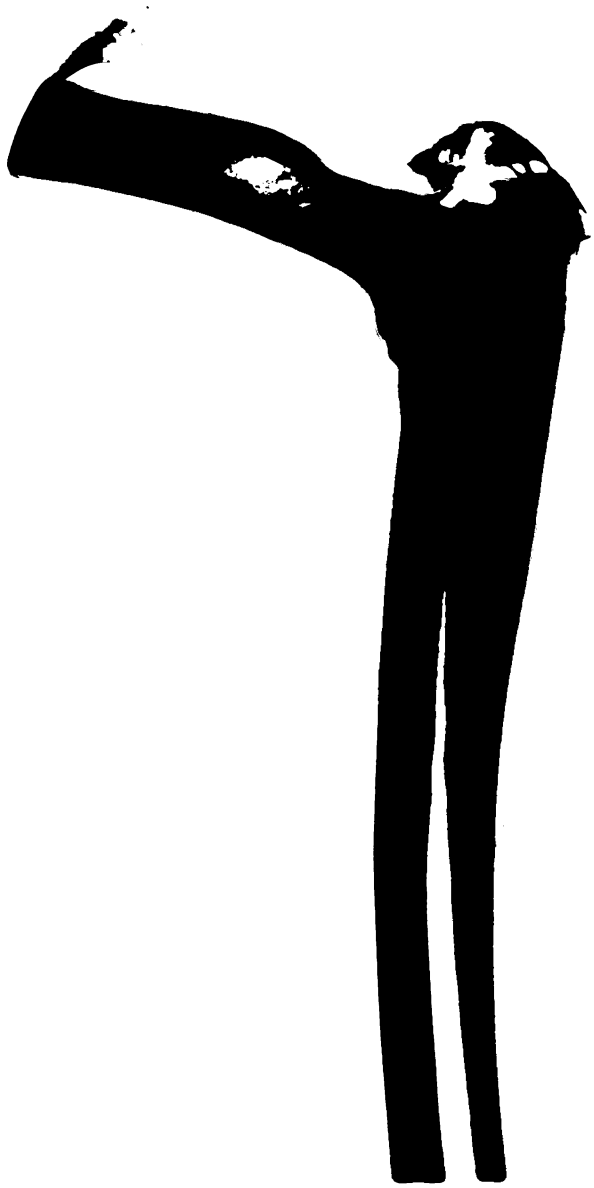
PLATE 20C

PLATE 20D



PLATES 21A-D

Case #34303 - Brittany Spaniel, male, six months old, see page 28.

An untreated three weeks old fracture of the lateral condyle of the left humerus.

Plate 21A*, page 86 - anteroposterior aspect of elbow prior to surgery.

Plate 21B, page 87 - mediolateral aspect of elbow prior to surgery.

Plate 21C**, page 88 - anteroposterior aspect postoperatively.

Plate 21D, page 89 - mediolateral aspect postoperatively.

* Plate reversed in printing. Plate appears as a right rather than a left elbow.

** Plate mislabeled. Should read AP instead of PA.

PLATE 21A

PLATE 21B

PLATE 21C

PLATE 21D

PLATES 22A-D

Case #34437 - Brittany Spaniel, spayed female, six years old, see page 28.

An untreated lateral condyle fracture of the right humerus of two months duration.

Plate 22A, page 90 - anteroposterior aspect of elbow prior to surgery.

Plate 22B, page 91 - mediolateral aspect of elbow prior to surgery.

Plate 22C, page 92 - anteroposterior aspect postoperatively.

Plate 22D, page 93 - mediolateral aspect postoperatively.

PLATE 22A

PLATE 22B

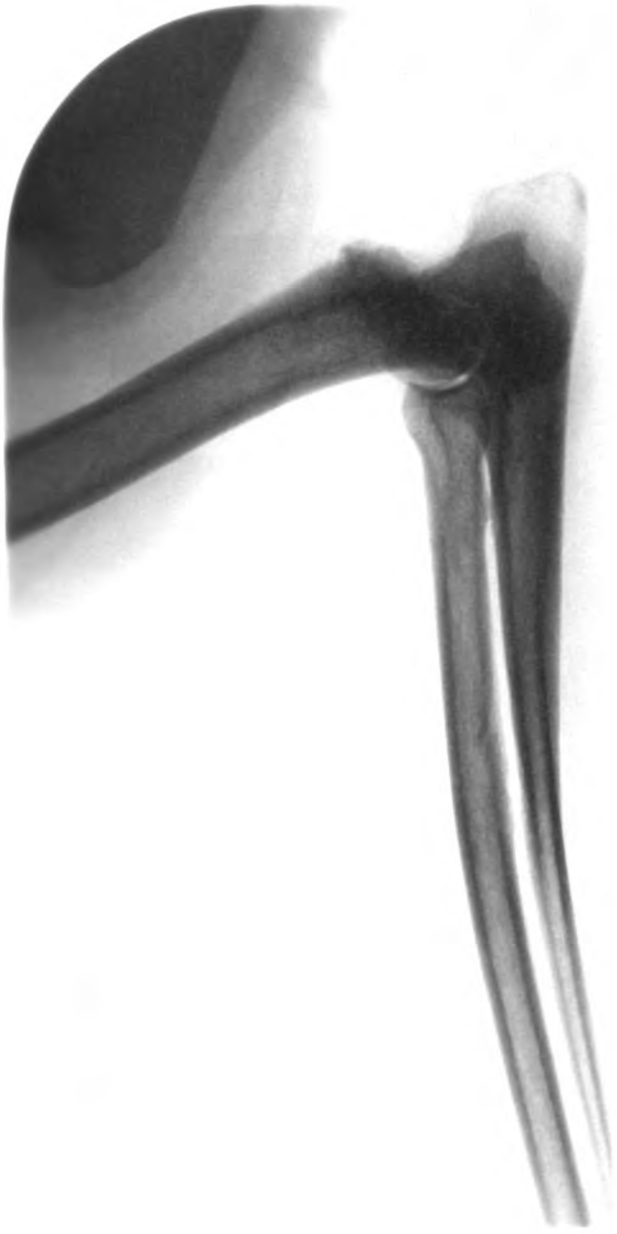
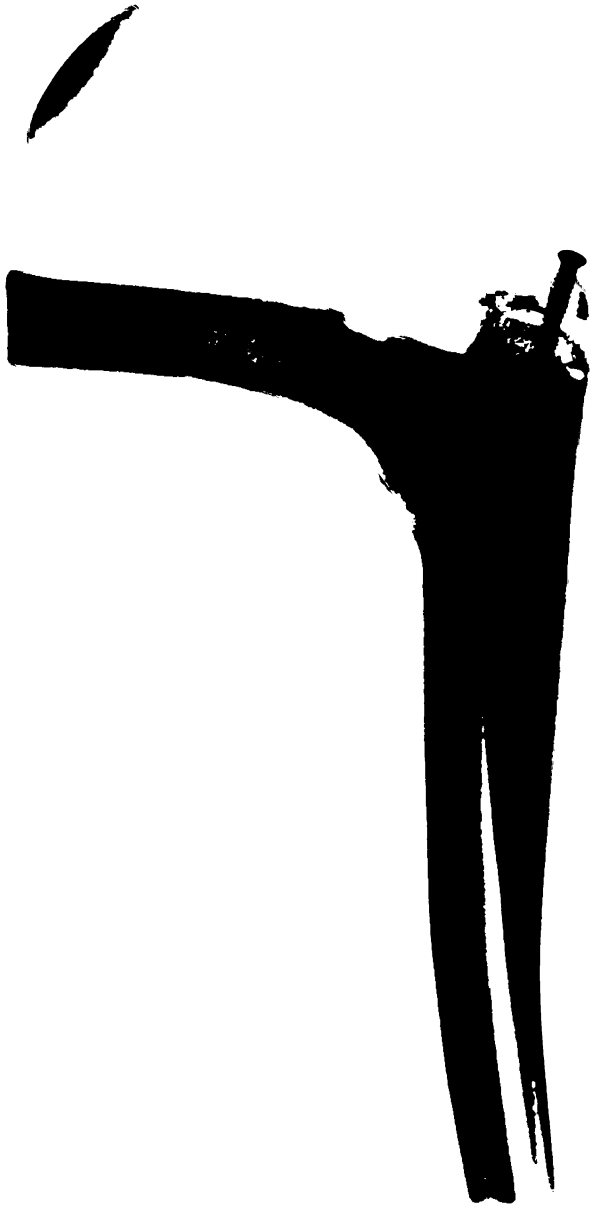


PLATE 22C

PLATE 22D



PLATES 23A-D

Case #36082 - English Bulldog, male, one and one-half years old, see pages 28 and 29.

An untreated fracture of the left lateral humeral condyle of four days duration. Muscle contracture and interposed muscle tissue prevented realignment and repair by means of a limited surgical approach.

Plate 23A, page 94 - anteroposterior aspect of elbow prior to surgery.

Plate 23B, page 95 - mediolateral aspect of elbow prior to surgery.

Plate 23C, page 96 - anteroposterior aspect postoperatively.

Plate 23D, page 97 - mediolateral aspect postoperatively.

PLATE 23A

PLATE 23B

PLATE 23C

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PLATE 24D

PLATES 24A-D

Case #36809 - Cocker Spaniel, male, two years old, see page 29.

An untreated five day old fracture of the left medial humeral condyle.

Plate 24A, page 98 - anteroposterior aspect of elbow prior to surgery.

Plate 24B, page 99 - mediolateral aspect of elbow prior to surgery.

Plate 24C, page 100 - anteroposterior aspect postoperatively.

Plate 24D, page 101 - mediolateral aspect postoperatively.

PLATE 24A

PLATE 243

PLATE 24C

PLATE 24D

PLATES 25A-D

Case #35222 - German Shephard, male, three years old, see pages 29 and 30.

An untreated three day old Y-fracture of the right humerus.

Plate 25A, page 102 - anteroposterior aspect of elbow prior to surgery.

Plate 25B, page 103 - mediolateral aspect of elbow prior to surgery.

Plate 25C, page 104 - anteroposterior aspect three months postoperatively.

Plate 25D, page 105 - mediolateral aspect three months postoperatively.

PLATE 25A

PLATE 25B

PLATE 25C

PLATE 25D

PLATES 26A-D

Case #35814 - Cocker Spaniel, male, five years old, see page 30.

A T-fracture of the left elbow of two weeks duration. Previous treatment with a Thomas splint was unsuccessful.

Plate 26A, page 106 - anteroposterior aspect of elbow prior to surgery.

Plate 26B, page 107 - mediolateral aspect of elbow prior to surgery.

Plate 26C, page 108 - anteroposterior aspect postoperatively.

Plate 26D, page 109 - mediolateral aspect postoperatively.

PLATE 26A

PLATE 26B

PLATE 26C

PLATE 26D

PLATES 27A-D

Case #35299 - Collie, male, five and one-half years old, see page 30.

An untreated lateral dislocation of the right elbow of three weeks duration.

Plate 27A, page 110 - anteroposterior aspect of elbow prior to surgery.

Plate 27B, page 111 - mediolateral aspect of elbow prior to surgery.

Plate 27C, page 112 - anteroposterior aspect one week post-operatively.

Plate 27D, page 113 - mediolateral aspect one week post-operatively.

PLATE 27A

PLATE 27B

PLATE 27C

PLATE 27D

PLATES 28A-C

Case #33050 - English Bulldog, male, six months old, see page 31.

An untreated fracture of the right lateral humeral condyle of four weeks duration.

Plate 28A, page 114 - anteroposterior aspect of elbow prior to surgery.

Plate 28B, page 115 - anteroposterior aspect postoperatively.

Plate 28C, page 116 - mediolateral aspect postoperatively.

PLATE 28A

PLATE 28B

PLATE 28C

PLATES 29A-D

Case #35513 - Brittany Spaniel, male, six years old, see page 31.

A three month old fracture of the lateral condyle of the left humerus. Previous treatment with a Thomas splint was unsuccessful.

Plate 29A, page 117 - anteroposterior aspect of elbow prior to surgery.

Plate 29B, page 118 - mediolateral aspect of elbow prior to surgery.

Plate 29C, page 119 - anteroposterior aspect postoperatively.

Plate 29D, page 120 - mediolateral aspect postoperatively.

PLATE 29A

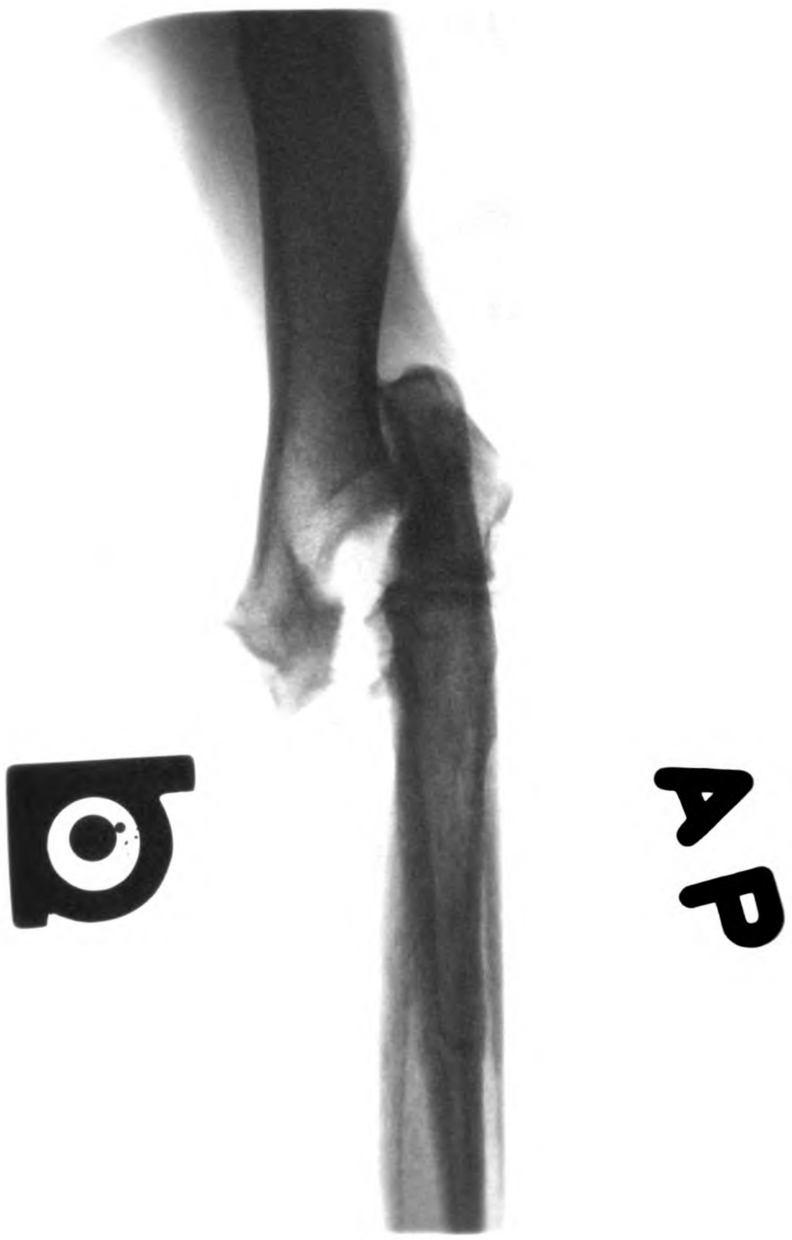


PLATE 29B

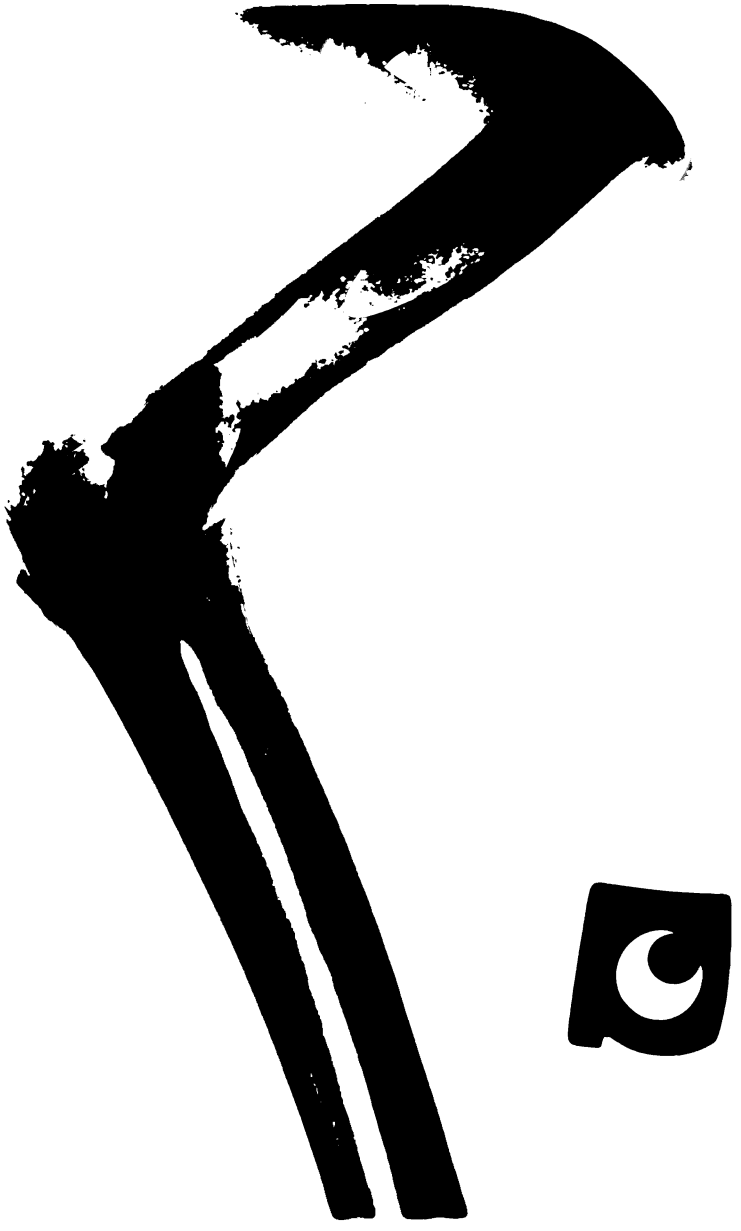
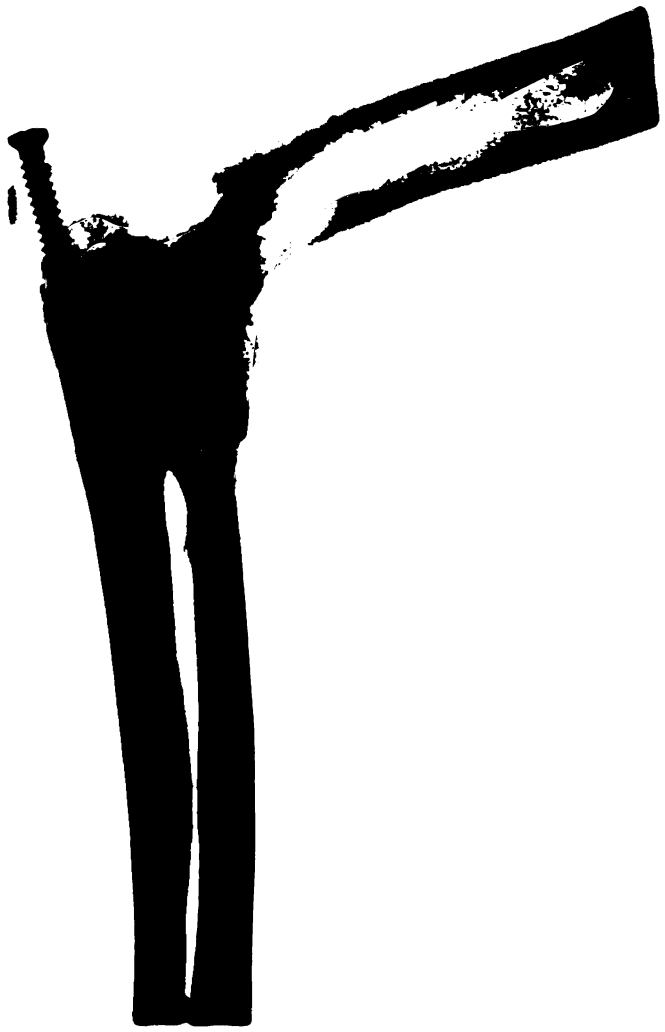


PLATE 29C

PLATE 29D



PLATES 30A-D

Case #36160 - Manchester Terrier, male, four months old, see pages 31 and 32.

An untreated fracture of the left lateral humeral condyle of ten days duration.

Plate 30A, page 121 - anteroposterior aspect of elbow prior to surgery.

Plate 30B, page 122 - mediolateral aspect of elbow prior to surgery.

Plate 30C, page 123 - anteroposterior aspect eight weeks postoperatively.

Plate 30D, page 124 - mediolateral aspect eight weeks postoperatively.

PLATE 30A

PLATE 30B

PLATE 30C

PLATE 30D

PLATES 31A-D

Case #3189 - Cocker Spaniel, male, ten years old, see page 32.

A Y-fracture of the left humerus which was repaired the same day as the injury occurred.

Plate 31A, page 125 - anteroposterior aspect of elbow prior to surgery.

Plate 31B, page 126 - mediolateral aspect of elbow prior to surgery.

Plate 31C, page 127 - anteroposterior aspect nine days post-operatively.

Plate 31D, page 128 - mediolateral aspect nine days post-operatively.

PLATE 31A

PLATE 31B

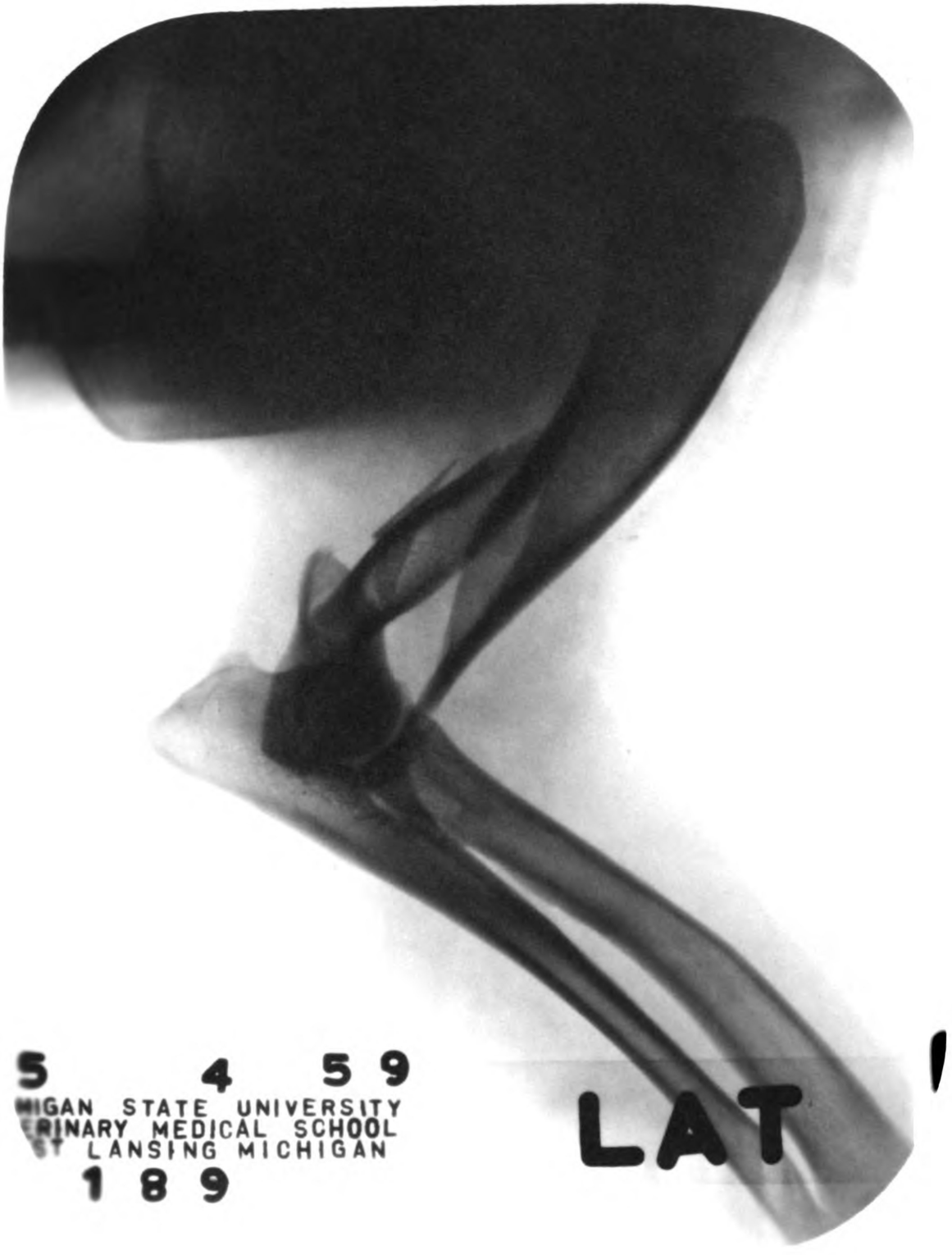

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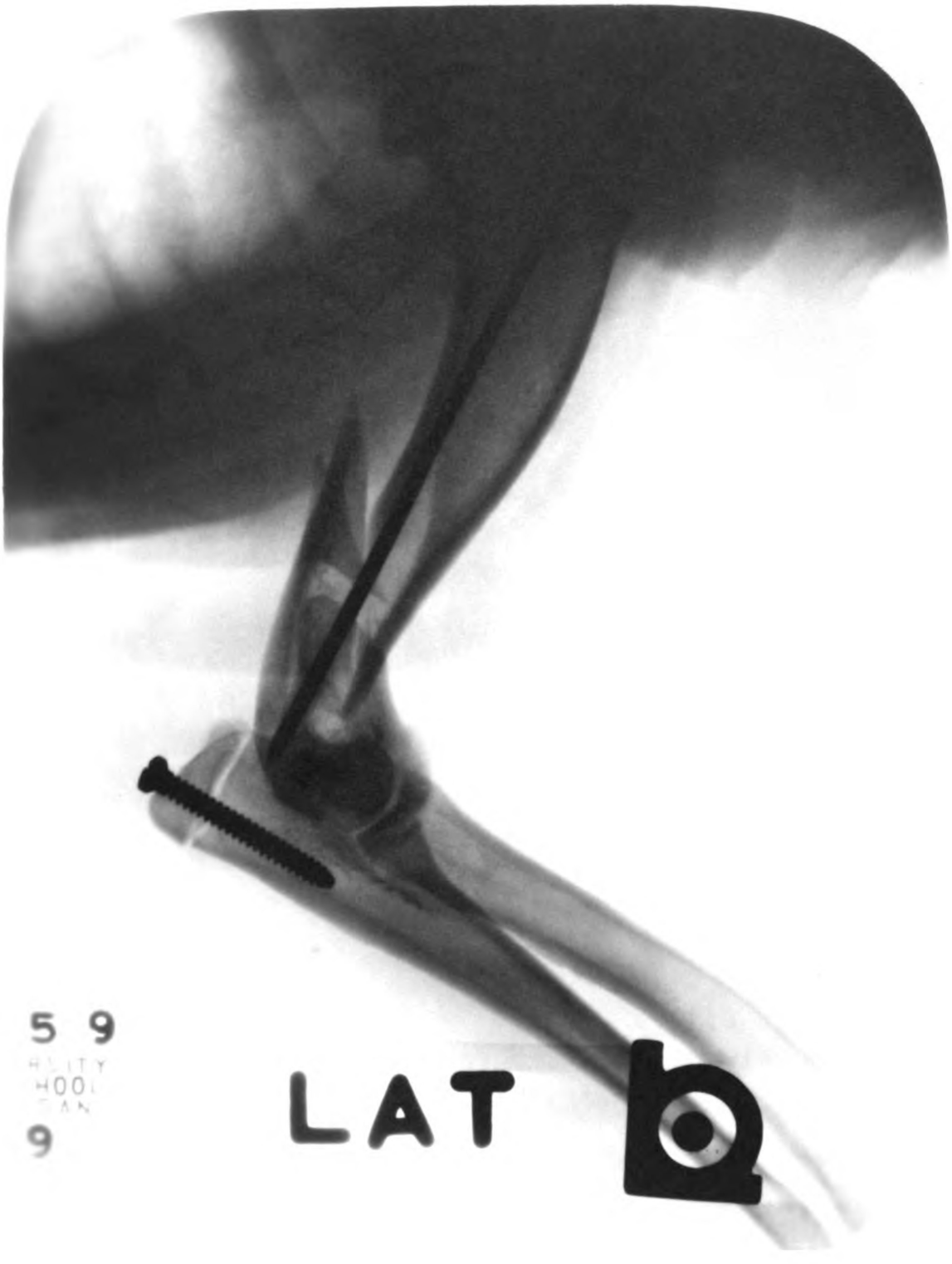
PLATE 31C

PLATE 31D



PLATES 32A-G

Case #31909 - Boxer, male, one year old, see page 32.

A one day old fracture of the lateral condyle of the left humerus was repaired by use of a limited surgical approach. Ten days postoperatively the intercondyloid bone screw broke. The trans-olecranon approach was used to remove the broken screw and insert a new screw.

Plate 32A, page 129 - anteroposterior aspect of elbow prior to surgery.

Plate 32B, page 130 - mediolateral aspect of elbow prior to surgery.

Plate 32C, page 131 - anteroposterior aspect postoperatively.

Plate 32D, page 132 - mediolateral aspect postoperatively.

Plate 32E, page 133 - anteroposterior aspect ten days postoperatively. Note broken intercondyloid bone screw.

Plate 32F, page 134 - anteroposterior aspect following trans-olecranon approach. Note removal of broken screw and insertion of new intercondyloid bone screw.

Plate 32G, page 135 - mediolateral aspect following trans-olecranon approach. Note removal of broken screw and insertion of new intercondyloid bone screw.

PLATE 32A

PLATE 32B

PLATE 32C

PLATE 32D

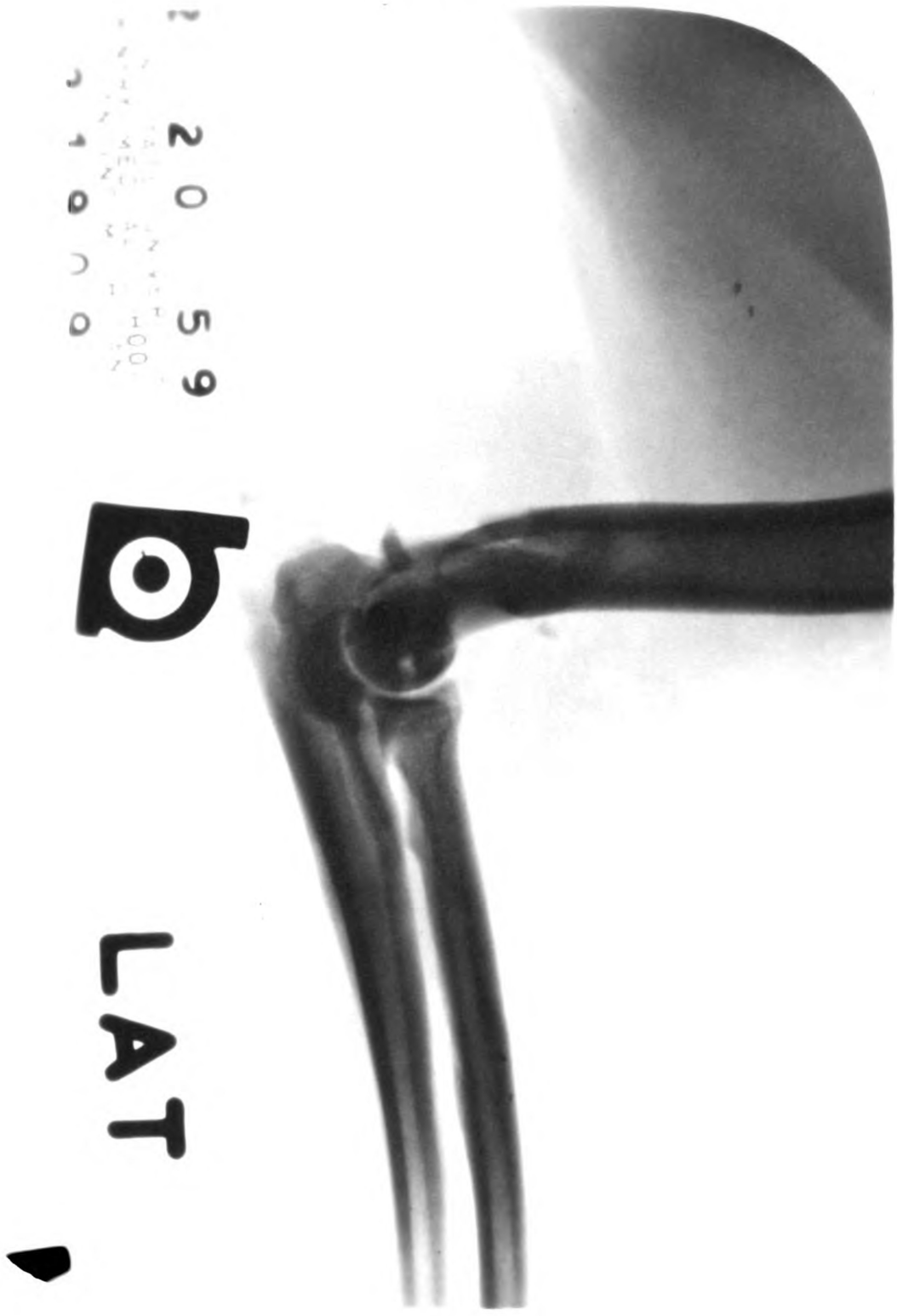


PLATE 52E

PLATE 32F

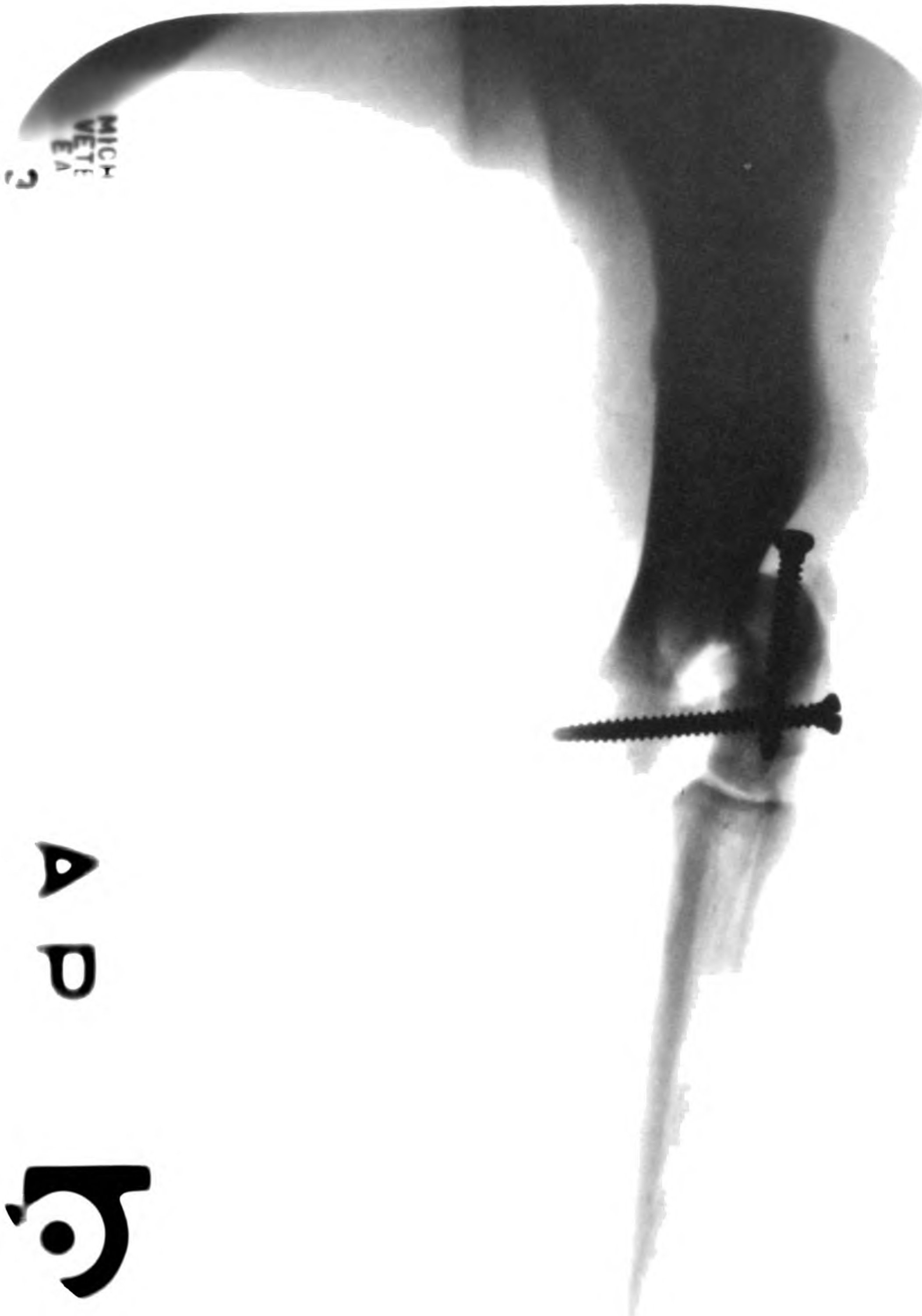


PLATE 32G

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