THE EXPERIMENTAL USE OF STAINLESS STEEL FEMORAL HEAD PROSTHESIS IN DOGS AND CATS

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Roger E. Brown

1960

THE EXPERIMENTAL USE OF STAINLESS STEEL FEMORAL HEAD PROSTHESIS IN DOGS AND CATS

by

Roger E. Brown

AN ABSTRACT

Submitted to the College of Veterinary Medicine
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Surgery and Medicine

1960

Approved: Wade O. Brinker Date: 3/15/60

ROGER E. BROWN ABSTRACT

An experimental replacement of the femoral head by a metal prosthesis was performed in four dogs and four cats. The surgical approach to the coxofemoral joint is described, along with a description of the replacement technique. Stainless steel, 18-8, type 303, was the material used for the prosthesis and its manufacture is described.

Functional use of the legs so altered was regained in seventy five percent of the cases. As surgical skill and technique progressed, the percentage of success increased. The longest period of observation on one animal was three years.

Post mortem findings showed pathology due to the prosthetic device was present in excess of what was suspected from clinical observation.

THE EXPERIMENTAL USE OF STAINLESS STEEL FEMORAL HEAD PROSTHESIS IN DOGS AND CATS

by

Roger E. Brown

A THESIS

Submitted to the College of Veterinary Medicine
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Surgery and Medicine

1960

ACKNOWLEDGMENTS

The author wishes to express his thanks to Dr. W. O. Brinker for his excellent suggestions on some of the technical aspects of this work. His daily interest in the project, his comments and corrections on portions of this thesis previously published, and the arrangement of a surgical demonstration of this procedure on television at a national veterinary convention was greatly appreciated.

He is indebted to Dr. B. V. Alfredson for the free use of the physiology workshop equipment, without which work like this could not have been undertaken.

The writer wishes to thank the late Dr. Frank Thorp Jr. for his suggestions as to study material, his assistance in reading and correcting portions of this thesis previously published.

To the late Dr. Lloyd B. Sholl, Miss Lilly Nemoto and Phyllis McAllen of the clinical pathology laboratory, he is greatly indebted for their help and guidance in doing the tissue work necessary.

The author greatly appreciates the time spent by Dr. Andrew C. Wheeler in taking radiographs of the animals and his advice as to their reproduction in a suitable form for thesis publication.

The writer is especially indebted to Dr. E. K. Sales and the Department of Surgery and Medicine for providing the surgical facilities, the laboratory animals with their care and maintenance, and the necessary materials without which the project could have been no more than a passing thought.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

For many years certain pathologic conditions of the hip joint have been the nemesis of the veterinary orthopedic surgeon. Some surgeons pass up these cases completely without attempting a corrective procedure. Others have attempted one or more of the many reconstructive procedures that have been advocated.

Treatment of fractures of the femoral head and neck in cats and dogs was such that non-union absorption of the neck and necrosis of the head were common and more likely to result than union. Other cases suggesting replacement were those showing arthritis of the coxofemoral joint, fractures of the pelvis through the acetabulum, avascular necrosis of femoral neck and head, congenital subluxation of the coxofemoral joint and traumatic dislocations that persist after standard procedures have failed.

Replacement of the upper end of the femur with foreign material can be accomplished if certain basic principles are understood. Reported herein are accounts of failure and success: a recording of observations in experimental cases: some comments on similar efforts of co-workers: some remarks on bone reaction to foreign material replacement of the femoral head and neck where load stresses are tremendous: and basic principles which point the way to further study and accomplishment by members of the veterinary profession.

II. REVIEW OF LITERATURE

The use of femoral head prostheses in the veterinary field has been limited. Experiments with foreign materials in bone (Bohlman, 1929) twenty-five years ago led to the choice of wood, twenty-two carat gold and platinum as usable materials. Guinea pigs were selected because of the cost of the materials involved and the availability of the animals. Two of each sex were used. A spherical head was devised which was mounted on a carpet tack shank sufficiently long to protrude obliquely through the short femoral neck and inter-trochanteric region. Operated legs soon displayed excellent motions and the pigs reproduced without apparent disturbance. No shank loosening occurred. Noting minimal reaction to woods in bone, a white oak piece was selected, soaked and boiled in Ringer's solution, dessicated in vacuum and autoclaved in bone wax. It was then turned to a well polished head on a tapered hexagonal shank and placed in a beagle hound's hip. The animal was reluctant to use her leg for two or three weeks but then became quite active, displaying good motion except in extreme ranges. Some work was done on plating steel with gold and platinum but porosity, cost of the procedure and technical difficulties prevented carrying their efforts to the clinical level.

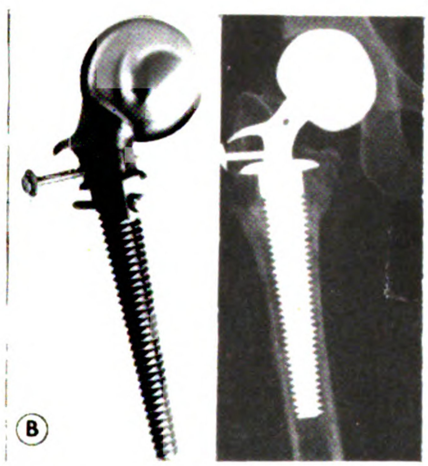
Experiments lapsed until the remarkable work of Venable and co-workers (1937), introducing Vitallium to the field of human bone surgery. This was followed by Venable's article (1938) on osteosynthesis in the presence of metals, and sometime after, another article by Venable and Stuck (1948) illustrating a Vitallium hip cup fixed on the upper end of the femur. Smith-Petersen's work (1939) is fundamental in the use of hip cups of various materials, antedating in concept that of any other worker; in 1938 he used Vitallium. Venable and Stuck (1948) placed a mold of this alloy in place of the upper end of the femur in a rabbit.

The earliest description of a surgical approach to the coxofemoral joint in the dog is by Bottarelli (1938). This article was abstracted in the North American Veterinarian. He describes a dorsal approach for surgical correction of coxofemoral luxations. The superficial and medial gluteal muscles were divided rather than severed to expose the joint capsule.

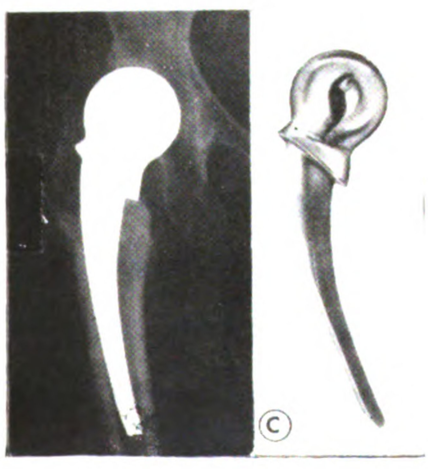
Loomis (1950), ten years ago, replaced the upper end of the human femur with a spherical head on a straight shaft supported by four flanges fitting over the shaft.

Archibald _et al_ (1953) describe an anterior surgical approach for the correction of luxations. This approach is also used for installing their plastic

Ⓐ **MOORE TYPE (Self-Locking) HIP**

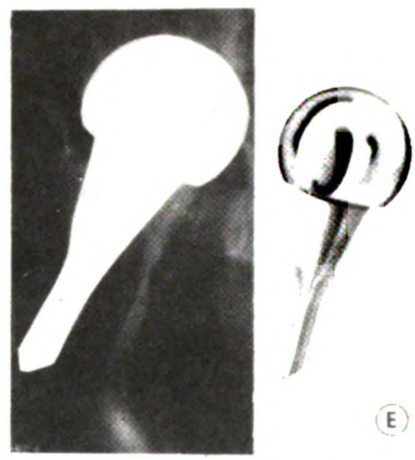


Ⓑ **McBRIDE TYPE (Door Knob) HIP**

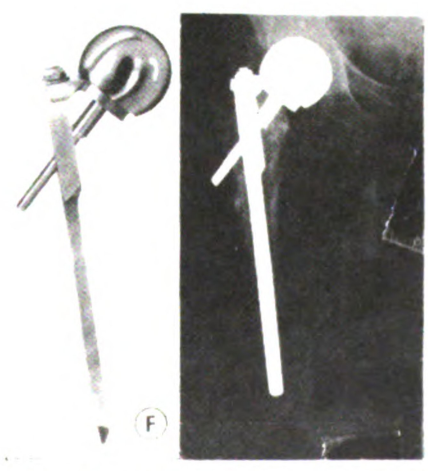


Ⓒ **F. R. THOMPSON TYPE HIP**

Ⓓ **MODIFIED JUDET TYPE HIP**



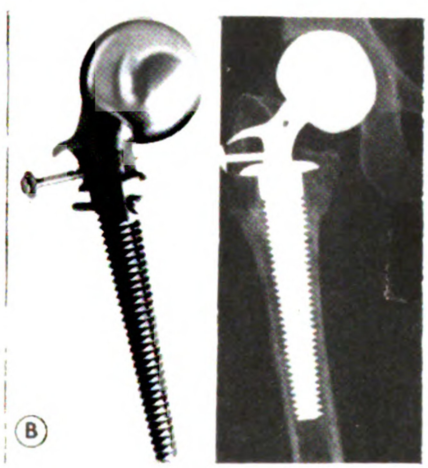
Ⓔ **J. E. M. THOMPSON TYPE**



Ⓕ **LIPPMAN TYPE HIP**

Figure 2

(A) MOORE TYPE (Self-Locking) HIP

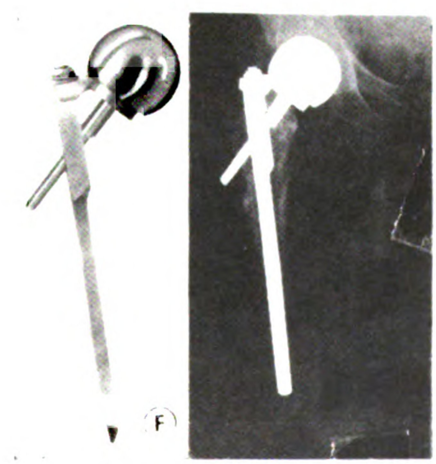


(B) McBRIDE TYPE (Door Knob) HIP

(C) F. R. THOMPSON TYPE HIP

(D) MODIFIED JUDET TYPE HIP

(E) J. E. M. THOMPSON TYPE



(F) LIPPMAN TYPE HIP

Figure 2

Judet type prosthesis.

McBride (1952) has devised an ingenious replacement. Remarkable is the trochanteric attachment, the method of embedding and the tapered threading which gives a vastly increased unit of surface pressure area and prevents the wedging effect of an appliance set in the medullary canal. McBride notes that where it is firmly embedded the reaction is that of proliferation, and where not firmly fixed, atrophy occurs.

Judet and Judet (1950) report a mushroom cap head on a stem of acrylic resin, later reinforced with a steel core. The brothers Judet reported (1952) on the use of acrylic plastic, this time on 400 human cases. Of these operations, 219 were for relief of osteoarthritis, 108 for congenital dislocations of the hip, and the balance for fractures of the femoral head and neck, septic and post traumatic arthritis, and other lesions.

Robert Jaenichen, in a discussion (1951) following the presentation of a paper of human prostheses, mentions that in 1944 he used a metal femoral head in a dog. Jacques Jenny reported (1952) on a case of a plastic femoral head and neck prosthesis to repair a poorly healed femoral neck fracture in a dog. He mentions previous similar operations.

Ausherman (1952) used a Vitallium femoral prosthesis in a setter dog in December of 1952 with in-

conclusive results as the animal succumbed to complications arising from the operation.

More recently Archibald (1953) reported on the use of a plastic prosthesis for use in femoral neck fractures in dogs and cats.

It would be necessary in cases of congenital subluxations to deepen the acetabulum to obtain a sufficient cup to prevent luxation of the steel prosthesis. The question will be raised as to the regrowth of cartilage in a reamed acetabulum. Gibson and Williams (1951) reported on the regrowth of cartilage on the head of the femur underlying a Vitallium cup. In this operation the head of the femur was reshaped and the articular cartilage was removed. In one woman who would not use the leg because of the pain present, no cartilage formed over the head of the femur, but only fiberous tissue, which was in places abnormal. In marked contrast, the newly formed joint had been used by the second patient freely and constantly for three and one-half years. In this case the head of the femur was covered by true articular cartilage, with healthy bone underneath and a smooth articular surface. The two specimens illustrated seem to demonstrate that tissue form and cellular type correspond to functional demand, and that for the reproduction of articular cartilage, compression plus gliding movement are a necessary combined stimulus.

This is in direct opposition to the views held by Sodeman (1950). He states in his book:

> It is important to note that cartilage has no blood supply. It derives nourishment from three sources:
> (a) from subchondral bone which is richly supplied with blood, but from which cartilage nutrient is poorly supplied, owing to the interface barrier;
> (b) from subsynovial vessels located at the junction of the capsule and the cartilage;
> (c) through the synovial fluid. The last is the chief source of nutrition. Growth of adult cartilage is entirely amitotic. It has been demonstrated that apposition of articular surfaces is required for maintenance of integrity in the articular cartilage. After experimental immobilization for sixty-two days, only the separated parts of the joint cartilage showed degeneration. Reaction of cartilage to injury differs, depending upon the depth of injury. Superficial cuts remain essentially unchanged for many months; if lesions do not extend to the subchondral bone or into the perichondrium, there is only slight proliferation. Wounds extending into the bone or located near the perichondrium or synovial surface are filled in rapidly with fibrous tissue. In the foregoing discussion it has been noted that regeneration of cartilage is virtually impossible, and experiments have repeatedly shown it to be negligible.

Here are two conflicting views on the regrowth of articular cartilage by prominent authors.

Surgical approach to the coxofemoral joint in human species was first described by Smith-Peterson (1917). Modifications of this method by many authors are in print (Gibson 1950) (Smith-Peterson 1949). Anatomy of the area's blood supply (Howe 1950) and nerve supply (Wertheimer 1952) in the human being makes enlightening reading to one entering this field of study. Miller's (1952) book on the anatomy of the dog is the standard of study and nomenclature in the veterinary field.

The chapters on fractures and joint injuries of human hip areas in Watson-Jones book (1952) provide one with lessons in anatomy, pathology and physiology as well as the treatments involved.

Authors of published articles on fractures involving the femoral neck are Colonna (1937), Gallie (1940), Leadbetter (1933), Patrick (1949), Phemister (1949), Smith-Peterson (1931), McMurray (1938) and Moore (1937).

Others reporting on femoral head prosthetics are Moore and Bohlman (1943) and Peterson (1951). Thompson and Epstein's (1951) survey on hip dislocations covering a 21 year period add to the material necessary for a full study of the problems connected with the coxofemoral joint.

III. EXPERIMENTAL STUDIES

A. Materials

1. The Prosthesis. The ideal prosthesis should fulfill the following requirements.

Head size. The femoral head prostheses should be as nearly the same size as the acetabulum as possible. It has been determined through these studies that the proper size femoral head may be selected by a direct measurement on a radiograph of the animal in question. The projection enlargement that occurs on the radiograph is compensated by the absence of the cartilage showing on the film. A measurement that falls between two available prostheses poses a problem. Experience has proved that the larger size is more satisfactory. Fig. 2 shows the drawings and dimensions of the twelve sizes of femoral head prostheses used in this study.

Head and neck length. The total length from the dome of the femoral head to the outer aspect of greater trochanter must be maintained if one is to avoid a residual abductor lurch. This total length is important, too, so that the tension of the muscles will keep the head in the acetabular socket and not permit subsequent dislocation.

Easy insertion. The prosthesis must be easy to insert, with minimal shock to the patient. It should

III. EXPERIMENTAL STUDIES

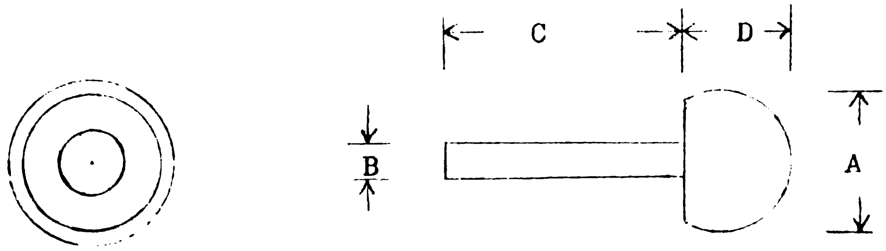
A. Materials

1. The Prosthesis. The ideal prosthesis should fulfill the following requirements.

Head size. The femoral head prostheses should be as nearly the same size as the acetabulum as possible. It has been determined through these studies that the proper size femoral head may be selected by a direct measurement on a radiograph of the animal in question. The projection enlargement that occurs on the radiograph is compensated by the absence of the cartilage showing on the film. A measurement that falls between two available prostheses poses a problem. Experience has proved that the larger size is more satisfactory. Fig. 2 shows the drawings and dimensions of the twelve sizes of femoral head prostheses used in this study.

Head and neck length. The total length from the dome of the femoral head to the outer aspect of greater trochanter must be maintained if one is to avoid a residual abductor lurch. This total length is important, too, so that the tension of the muscles will keep the head in the acetabular socket and not permit subsequent dislocation.

Easy insertion. The prosthesis must be easy to insert, with minimal shock to the patient. It should



Part No.	Dim.A.	Dim.B.	Dim.C.	Dim.D.
16	1.000	.250	1.50	.713
15	.937	.250	1.43	.646
14	.875	.250	1.37	.625
13	.812	.218	1.31	.578
12	.750	.218	1.25	.531
11	.687	.187	1.19	.484
10	.625	.187	1.13	.437
9	.562	.156	1.06	.390
8	.500	.156	1.00	.343
7	.437	.125	.88	.296
6	.375	.125	.75	.250
5	.312	.094	.62	.208

1. Material: CRS 18-8 type 303

Figure 2

not require special tools, as this will limit its use in most veterinary hospitals. The Judet type prosthesis used in these studies is as simple a type of femoral head replacement that is in use in the human field today.

Sterility. The prosthesis should be capable of complete autoclaved sterility before being inserted.

One-piece appliance. It should be composed of one piece of metal and not of two or more pieces, since whenever two or more pieces are placed within the body they can sooner or later come apart, or they are apt to break. This may not occur immediately, but months later, at the site of the junction of the two pieces.

A two piece appliance may form a battery action within the body, with subsequent decalcification of the bone and failure of the surgical procedure.

Coxa Vara. The prosthesis should give assurance, by its shape, or in the engineering principles employed, that it will not allow subsequent development of coxa vara.

Incorporation of prosthesis with bone. An important criterion for the ideal prosthesis is the property of being ultimately so incorporated or fixed to the bone that its stresses will be evenly distributed through-out the femoral shaft without any motion, so that it becomes practically a part of the bone.

Nonelectrolytic metal. The material should be made of nonelectrolytic metal which can never form a battery within the body. It is better to have the prosthesis of metal than of an acrylic plastic or nylon, since many failures of these materials have been recorded. Newman and Scales (1951) reported on the unsuitability of polythene for weight-bearing prostheses. Their case demonstrated that polythene, if used in a situation in which it is subjected to abrasion, will abrade; and that the particles so formed will simulate a marked foreign body reaction, with giant-cell formation and fibrosis. The plastic hip cup wore through at fifteen weeks and a Vitallium cup was substituted. Bickel and Babb (1948) reported that eleven fractured lucite cups were removed and replaced with Vitallium at the Mayo Clinic. Venable and Stuck (1948) conducted studies of 18-8 stainless steel plus molybdenum, 19-9 stainless steel passivated in nitric acid, Vitallium, and tantalum. Their conclusions were as follows: Vitallium, 19-9 stainless steel, and 18-8 SMo stainless steel were inert in the tissues in descending order of excellence. Combinations of these metals should not be used in any single operation. The ability to withstand functional strain during the healing period is greater in the stainless steels

of the bone.

Nonelectrolytic metal. The material should be made of nonelectrolytic metal which can never form a battery within the body. It is better to have the prosthesis of metal than of an acrylic plastic or nylon, since many failures of these materials have been recorded. Newman and Scales (1951) reported on the unsuitability of polythene for weight-bearing prostheses. Their case demonstrated that polythene, if used in a situation in which it is subjected to abrasion, will abrade; and that the particles so formed will simulate a marked foreign body reaction, with giant-cell formation and fibrosis. The plastic hip cup wore through at fifteen weeks and a Vitallium cup was substituted. Bickel and Babb (1948) reported that eleven fractured lucite cups were removed and replaced with Vitallium at the Mayo Clinic. Venable and Stuck (1948) conducted studies of 18-8 stainless steel plus molybdenum, 19-9 stainless steel passivated in nitric acid, Vitallium, and tantalum. Their conclusions were as follows: Vitallium, 19-9 stainless steel, and 18-8 SMo stainless steel were inert in the tissues in descending order of excellence. Combinations of these metals should not be used in any single operation. The ability to withstand functional strain during the healing period is greater in the stainless steels

than in the Vitallium plates and screws which were tested. Stainless steel should be surface marred as little as possible during application. If badly scratched or abraded they are subject to increased corrosion in the tissues. Following bending, deep surface scratching or severe strain, stainless steel plates and screws show increased corrosion in the tissues and increased liability to breakage from fatigue strain. The steels, after such bending, develop anodic and cathodic points which become specific foci for corrosion. This was a much worse complication than the formation of crystals or cracks. Type 410 and type 431 stainless steels, both of which are Martensitic alloys, are magnetic, electrolytic and subject to corrosion. These steels will on occasion form rust granuloma.

Machining and polishing. The present dimensions of shaft length and size to head length and size were achieved only after many experimental trials. Fig. 2 lists the dimensions of twelve femoral head prosthesis. Considerable time was spent in planning the type of prosthesis desired. Several modified Judet shell type (Fig. 1-D) prosthesis were made at the onset. These proved to be impractical from a standpoint of machining difficulties and the trouble encountered in surgical placement.

The material used in this work was 18-8 stain-

less steel, type 303 purchased in ten foot lengths and machined in an engine lathe to the sizes needed. Stainless steel was easily machined, requires no special casting process as compared to Vitallium, was unbreakable and not subject to wear as compared to plastic, and was inexpensive. The shaft and head were turned from one piece, so there was no danger of separation after installation. Also, the possibility of creating an electrolytic reaction if two slightly different types of metal were incorporated into the head and shaft, was eliminated. After the head was machined, it was polished to a very smooth finish. It should be remembered that a polished surface is a series of parallel scratches. If these tiny scratches are of sufficient size, then every movement of the joint will remove a few cells of cartilage from the acetabulum and cause eventual failure of the surgical procedure through development of pain in the eroded acetabulum. Following the polishing operation, the stainless steel was given a twenty minute soak in a solution of nitric acid to remove surface impurities on the metal as a result of the polishing operation. This procedure is called passivation by the metal-finishing industry. The heads were wrapped and stored to prevent damage until use.

2. Experimental Animals.

The dogs used in the experimental stage of de-

less steel, type 303 purchased in ten foot lengths and machined in an engine lathe to the sizes needed. Stainless steel was easily machined, requires no special casting process as compared to Vitallium, was unbreakable and not subject to wear as compared to plastic, and was inexpensive. The shaft and head were turned from one piece, so there was no danger of separation after installation. Also, the possibility of creating an electrolytic reaction if two slightly different types of metal were incorporated into the head and shaft, was eliminated. After the head was machined, it was polished to a very smooth finish. It should be remembered that a polished surface is a series of parallel scratches. If these tiny scratches are of sufficient size, then every movement of the joint will remove a few cells of cartilage from the acetabulum and cause eventual failure of the surgical procedure through development of pain in the eroded acetabulum. Following the polishing operation, the stainless steel was given a twenty minute soak in a solution of nitric acid to remove surface impurities on the metal as a result of the polishing operation. This procedure is called passivation by the metal-finishing industry. The heads were wrapped and stored to prevent damage until use.

2. Experimental Animals.

The dogs used in the experimental stage of de-

veloping the technique of inserting femoral head prostheses were obtained from a city operated dog pound. The dogs were mongrels of all sizes and ages, however most of them were young dogs. They were housed in concrete cages and turned loose in a pen twice a day while cage cleaning took place. Exercise was limited to the few minutes each day while the dogs were in the pen. The food was Fromm's meal, fed dry and free choice with fresh water available in pans, The dogs were given canine distemper antiserum on arrival from the pound. Those obviously sick with distemper were used for other purposes. It was inevitable that some bitches would be bred in the community pen method of exercise. Most of the experimental animals on this diet developed a skin disorder. Scrapings of the epithelium were negative for parasites. Later when one of these dogs was started on a different diet (tablescraps and milk) the skin trouble disappeared in three weeks.

The cats used were obtained as needed from local sources. They were housed and fed in the same manner as the dogs.

B. Methods.

1. Surgical Preparation.

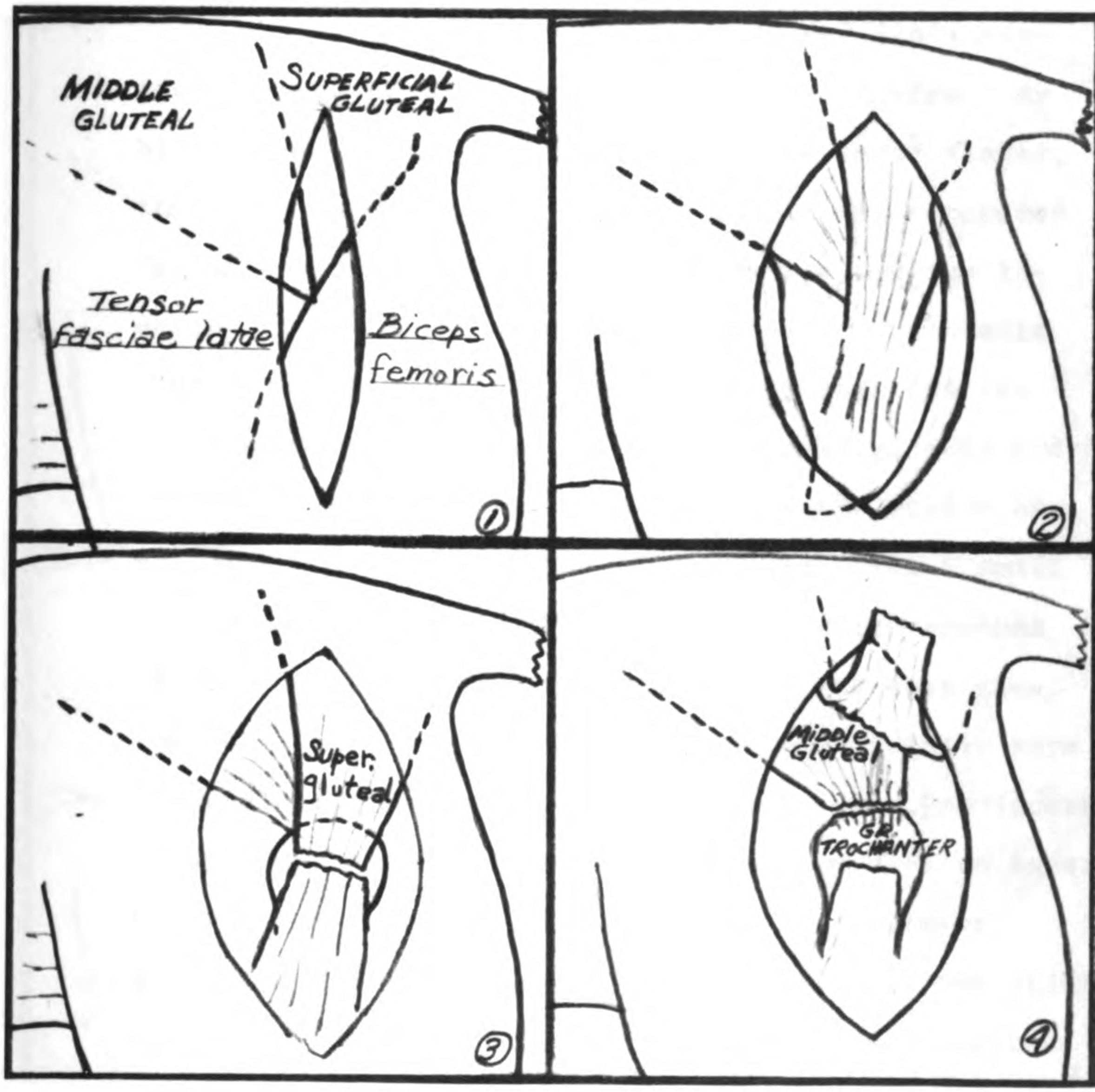
The surgical anesthetic used throughout these studies was sodium pentobarbital administered intravenously to effect. Duration of anesthesia was

sufficient in most cases; occasionally it was necessary to give additional amounts if the surgical time exceeded one hour.

The hair was removed from the dorsal midline to the stifle and from the flank to the rectum with Oster clippers using a #40 blade. The loose hair was carefully brushed and blown from the area. The surgical scrub of the operative site was carried out with a liquid germicidal detergent diluted to one part in four with water. Three scrubs were considered sufficient preparation. The area was draped with sterile cotton shrouds folded to double thickness. Later in some cases, a stockinette was applied to the leg. The great trochanter of the femur was used as a centering landmark for the draping procedure.

2. Surgical Approach to the Coxofemoral Joint (Brown, 1953).

The skin incision was made directly over the trochanter (Fig. 3-1) and from three to six inches long, depending on the size of the patient. The incision was deepened through the subcutaneous tissues until the anterior margin of the biceps muscle was identified. The biceps and the tensor fasciae latae were separated with scissors at their junction. The biceps was reflected posteriorly and the tensor fasciae latae anteriorly (Fig. 3-2) to expose the superficial gluteal muscle and its convergence to an aponeurosis



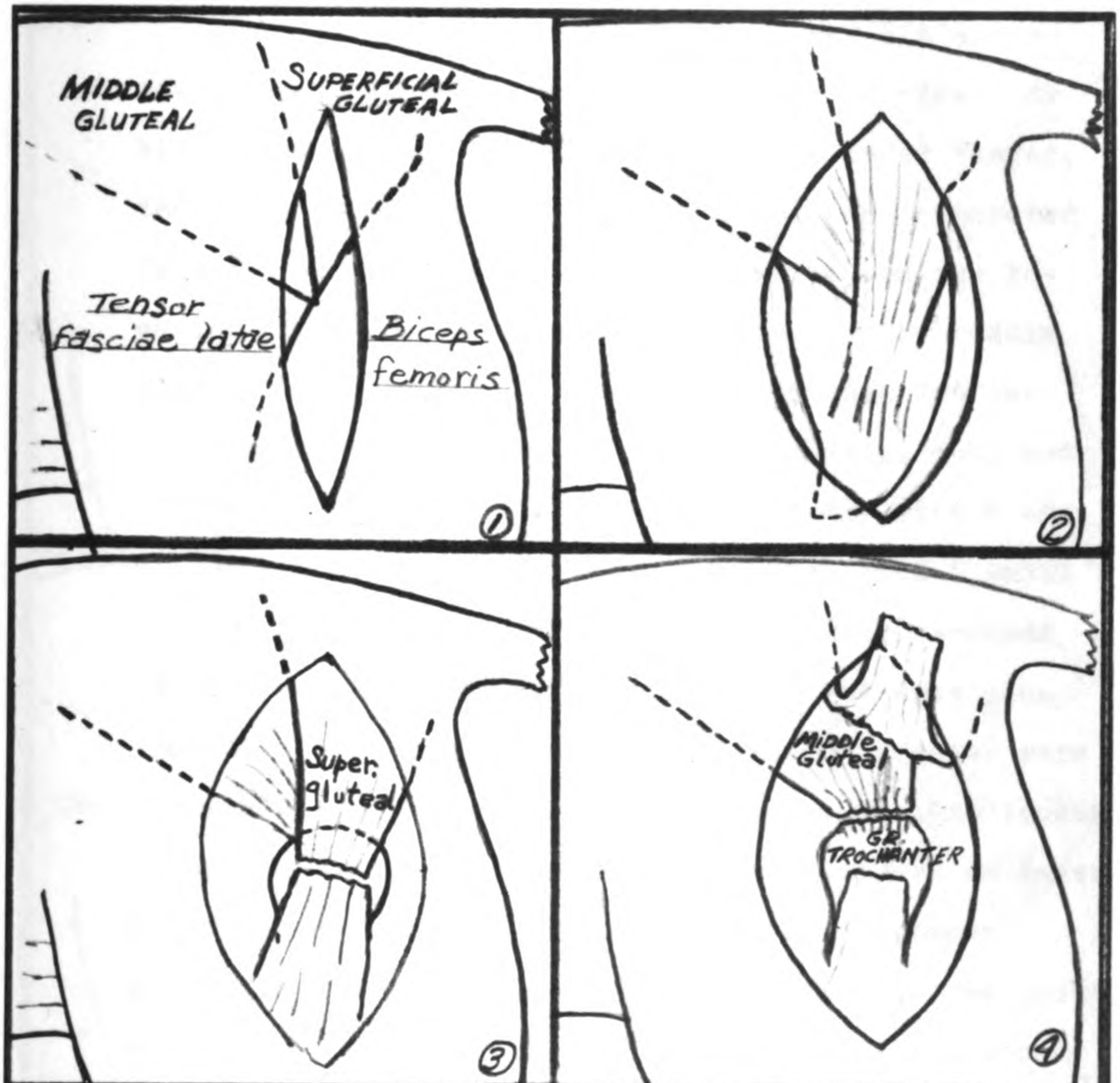
1. Location of skin incision.

2. Division of biceps femoris and tensor fasciae latae.

3. Superficial gluteal severed.

4. Middle gluteal severed.

Figure 3



1. Location of skin incision.

2. Division of biceps femoris and tensor fasciae latae.

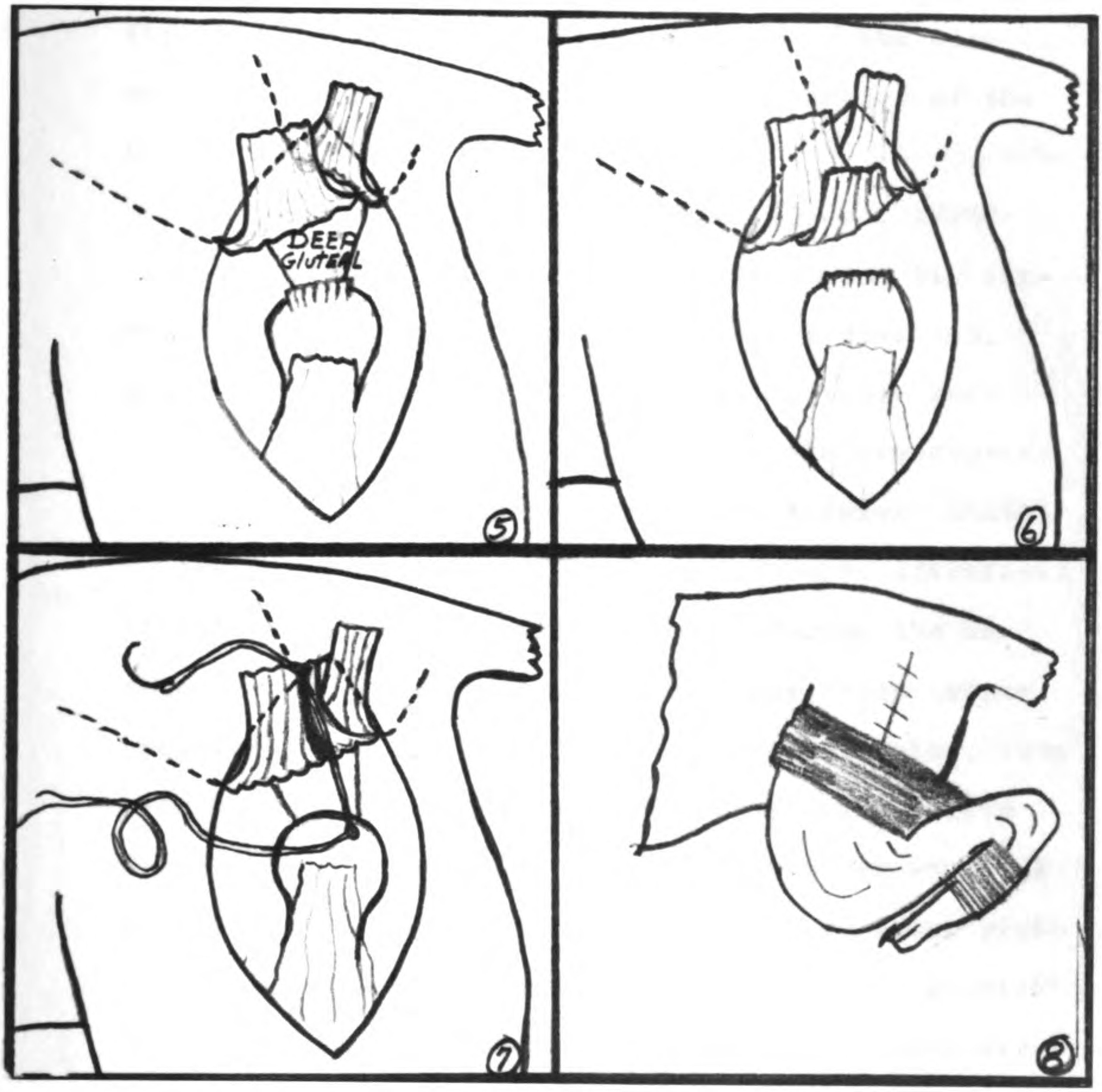
3. Superficial gluteal severed.

4. Middle gluteal severed.

Figure 3

which attaches to the third trochanter. The aponeurosis is cut directly over the great trochanter (Fig. 3-3) and the muscle dorsally reflected (Fig. 3-4).

The large middle gluteal muscle and its insertion into the great trochanter was now in view. By blunt dissection, preferably using the index finger, the belly of the middle gluteal muscle was separated from the underlying deep gluteal muscle and the location of the sciatic nerve determined. The middle gluteal was severed with a scalpel through its insertion close to the great trochanter (Fig. 4-5) and the muscle dorsally reflected (Fig. 4-6). There was slight hemorrhage observed at this time from a small branch of the anterior femoral artery which ascends to the muscle through its insertion. The deep gluteal and its insertion into the great trochanter were now visible. The belly of this muscle was also loosened by blunt dissection and scissors were used to sever its fibrous insertion, care being taken to leave enough of the insertion for later suturing. The joint capsule was now exposed in its entire dorsal circumference. The dorsal rim of the acetabulum and the dorsal portion of the femoral head could now be easily palpated under the joint capsule. The joint capsule was opened by nicking with a scalpel and small scissors used to complete an opening in the dorsal hemisphere of the capsule. The femoral head may be



5. Identification of deep gluteal muscle.

6. Deep gluteal severed.

7. Suturing middle gluteal to trochanter major.

8. Single sling applied.

Figure 4

partially luxated now, enough so that a small curved scissors may be used to sever the ligamentum teres. A round-pointed, grooved bone chisel was suitable for this purpose also. This severing of the ligamentum teres allows for a complete luxation of the head.

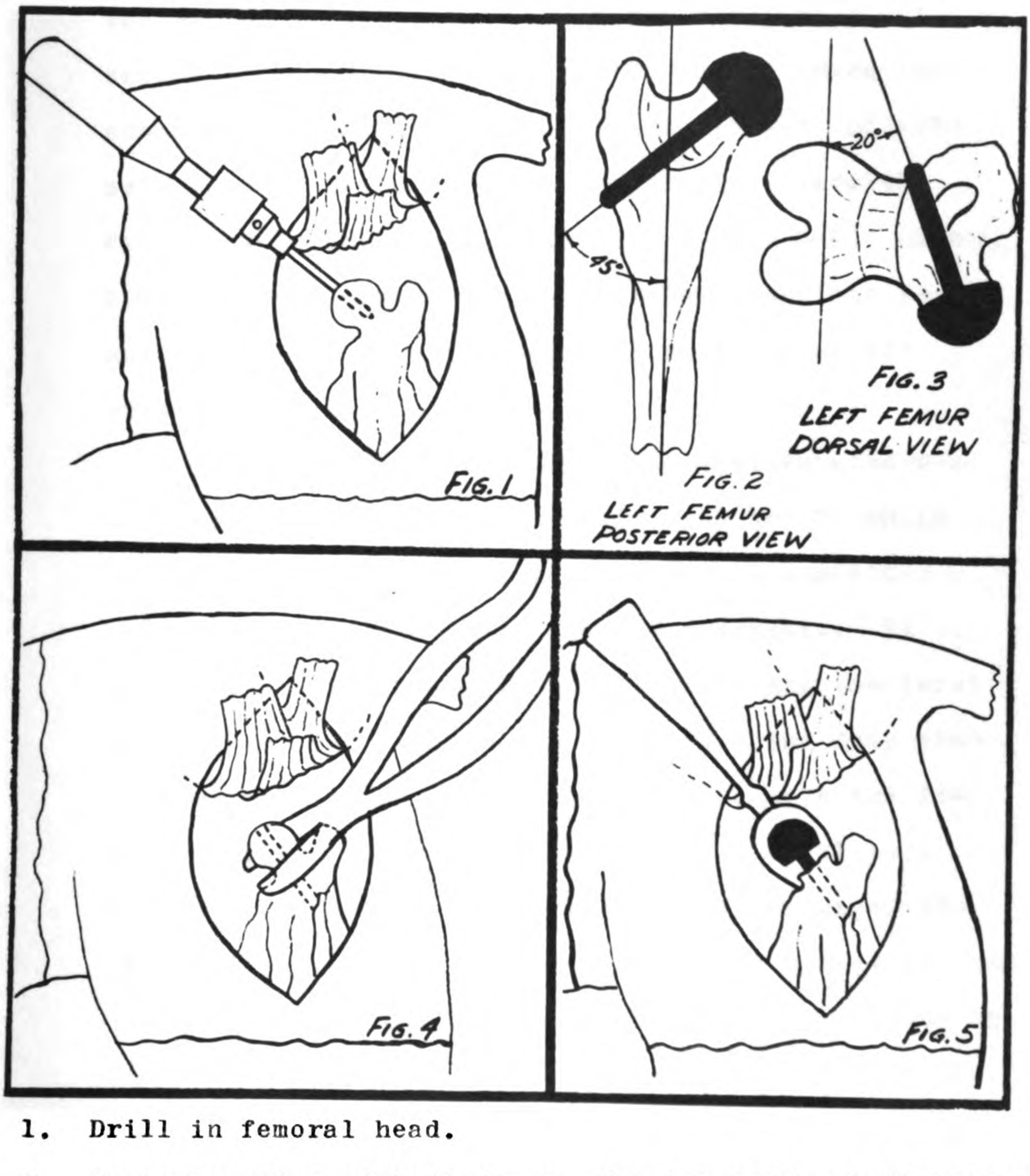
3. Installation of Prosthesis (Brown, 1953)

The acetabulum is checked to determine its condition. In traumatic luxations of some duration, there was a displacement of the soft tissues surrounding the acetabulum. There is a shallow depression in the lower quadrant of the acetabulum, distal to the ligamentum teres, filled with loose fibrofatty tissue called the haversian gland. During the absence of the femoral head in luxations, this tissue proliferates and partially fills the acetabulum, thus preventing proper seating of the prosthesis. This fibro fatty tissue could usually be removed with the index finger as a curette. The stainless steel prosthesis may be slipped into the acetabulum as a check on the preparation. The deepening of the boney acetabulum in congenital dislocations or subluxations was done with a ball shaped reamer. These reamers were purchased from a tool supply company as the proper size was not available from surgical supply houses. The reamer was used in the hand chuck to remove the acetabular cartilage and bone until a

proper depth of seating was obtained.

In those cases involving femoral head and neck fractures, a 3/32-inch threaded Kirschner pin screwed into the broken fragment will provide enough traction to enable the surgeon to free it from its muscle and ligamentous attachments. The remaining stump was shaped to give the desired seating of the prosthesis. In those cases having a femoral head showing lesions (osteoarthritis, congenital subluxations, and other conditions), the head was severed at right angles to the femoral neck (Fig. 5-4).

An intramedullary pin of the same size as the shaft of the prosthesis was used to drill a hole through the femoral head and neck, across the medullary canal and out through the cortex below the trochanter major (Fig. 5-1). The angle between the prosthesis and the femoral shaft is about 45 degrees as shown in Figure 5-2. The normal anteversion of the femoral neck to a transverse plane through the femur is about 20 degrees, as shown in Figure 5-3. The correct location of this hole was one of the most important steps in the operation and a few minutes were well spent in getting the anatomical relationship before drilling. On older animals an intramedullary pin could be passed only with difficulty, so a stainless steel drill of the proper size was recommended to save time. This drill was used in the



1. Drill in femoral head.

2. Posterior view of left femur, showing angle of 45 degrees between prosthesis and long axis of femoral shaft.

3. Dorsal view of left femur, showing prosthesis at angle of 20 degrees to a transverse plane through the femur.

4. Severing femoral head at right angle to femoral neck.

5. Prosthesis inserted into drilled hole in femur.

Figure 5

Kirschner hand drill-chuck in the same manner as an intramedullary pin.

At this point, the surgical assistant rotated the stifle joint outward and applied traction laterally to the proximal end of the femur. Here the common teaspoon is useful to repell tissue and act as a guide. The prosthesis was inserted into the drilled hole and tapped into place (Fig. 5-5). The head was then seated in the acetabulum and the femur held in an abducted position with the stifle rotated inward.

The surgical closure of the operative side was effected in the following manner with No. 50 white cotton thread. A small, full-curved atraumatic needle was used to suture the joint capsule. It was desirable to leave a slight gap inside the joint capsule for the escape of hemorrhage. The deep gluteal muscle is sutured in several places in the fibrous portion where it was severed. A small hole was drilled through the dorsal lip of the great trochanter (Fig. 4-7) and a doubled suture passed through it and into the thick band of fibrous tissue found in the posterior one-third of the middle gluteal muscle.

If the dog's leg was elevated slightly at this time, the muscle contraction which had taken place was corrected and suturing was much easier. Additional sutures were taken in the fascia of the middle

gluteal to rejoin it where it was severed. The superficial gluteal muscle was returned and sutured at its division point. The biceps femoris and the tensor fasciae latae was returned to their normal positions and sutured together. Sutures were placed in the subcutaneous tissue to approximate the skin and closure is completed with simple interrupted sutures. An adequate number and the proper placing of non-absorbable sutures are very important in the closure of this approach to the coxofemoral joint.

4. Aftercare.

Postoperative care consisted of applying a single sling bandage to the leg (Fig. 4-8) to prevent weight-bearing on this limb. This was allowed to remain for five days, at which time it was safely removed if the animal had a separate kennel and exercise run. The animals did not receive antibiotics with one exception.

C. Presentation of Cases.

Dog #1. A small black and white dog named Peggy was selected for the first case. She was an extremely active dog and barked incessantly. December 9th, 1952 the first steel prosthesis was installed on the left hip. It was a two piece modified Judet type and the shaft was cut to length after installation was completed. This proved unsatisfactory as it left sharp, ragged corners as shown on the radiograph (Fig. 6). From this time on, the shaft length was determined before surgery. However, the sharp edges of the shaft did not seem to interfere with muscle function in this area. Peggy was spayed December 23rd and found to be pregnant. Hip action was good and the first operation termed a success. The right hip underwent surgery February 12, 1953. A half inch ball, one piece Judet type prosthesis was used. February 16th the dog jumped out of her third tier cage and luxated the right coxofemoral joint containing the recently installed prosthesis. The dog was anesthesized and the hip reduced in the manner of a normal luxation and a single sling bandage applied. The sling was left in place fourteen days. Functional use of this leg was observed several days after sling removal. This dog was adopted out into a private home in June so that the case could undergo conditions of an average house pet. She was an

C. Presentation of Cases.

Dog #1. A small black and white dog named Peggy was selected for the first case. She was an extremely active dog and barked incessantly. December 9th, 1952 the first steel prosthesis was installed on the left hip. It was a two piece modified Judet type and the shaft was cut to length after installation was completed. This proved unsatisfactory as it left sharp, ragged corners as shown on the radiograph (Fig. 6). From this time on, the shaft length was determined before surgery. However, the sharp edges of the shaft did not seem to interfere with muscle function in this area. Peggy was spayed December 23rd and found to be pregnant. Hip action was good and the first operation termed a success. The right hip underwent surgery February 12, 1953. A half inch ball, one piece Judet type prosthesis was used. February 16th the dog jumped out of her third tier cage and luxated the right coxofemoral joint containing the recently installed prosthesis. The dog was anesthesized and the hip reduced in the manner of a normal luxation and a single sling bandage applied. The sling was left in place fourteen days. Functional use of this leg was observed several days after sling removal. This dog was adopted out into a private home in June so that the case could undergo conditions of an average house pet. She was an

extremely active little animal and roamed the area for blocks around. Three years following the surgery she gave evidence of increasing tenderness in the area of the greater trochanters and would attempt to bite if touched. The family had three small children and could not risk their injury so the animal was euthanized. Postmortem examination of the surgical sites revealed a loosening of the prosthetic shaft in the bone. Radiographs revealed a pie-shaped area of decalcification distal to the lateral portion of the shaft of the prosthesis and another ventral to the medial portion of the shaft. The acetabulum on both sides was normal on gross examination. It is interesting to note that the two piece prosthesis had a far greater range of motion in the shaft hole indicating increased osteoporosis. The possibility of a battery action between slightly different types of metal could account for this happening.

Figure 6

Dog #2. A collie-type female dog weighing about thirty-five pounds was selected. A 3/4 inch ball, two piece prosthesis was inserted by surgery on December 23, 1952. This ball was too large for the acetabulum and was selected to check the reaction of the acetabular cartilage to pressure unevenly distributed on the surface (Fig. 7). The dog favored the leg slightly for about a month. Pregnancy issued and three pups were whelped February 2, 1953 and raised to weaning age by the animal. The dog was sacrificed on May 20th. Sections of the acetabulum and shaft site were excised. Grossly the rim of the acetabulum showed necrosis and loss of smooth appearance. The material was fixed, decalcified and embedded in the method described by McNamara, <u>et</u> <u>al</u>, (1940). Microscopic section of the acetabulum showed loss of the articular cartilage on the rim where pressure was greatest. It must be noted that in spite of this necrosis the gait was very nearly normal and functional use present with no evidence of pain.

Figure 7

Dog #3. This was a 25 pound female, brown and white, mongrel dog. A two piece femoral head prosthesis, modified Judet type, was installed in the left side on December 30th, 1952. Dr. Brinker assisted in the surgery. This prosthesis was a shell type and only the articular cartilage of the femoral head was removed. Skin sutures were removed and the dog was spayed January 4th, 1953. One month later a prosthesis was installed in the right coxofemoral joint. This was a half-inch diameter ball and 5/16 inch shaft. The head had a 1/32 inch undercut. Radiographs (Fig. 8) were taken of the hip area and copies forwarded to Dr. Archibald for use in his experimental surgery book. This animal had very good functional use of the rear legs. Euthanasia and post-mortem of this case two months later revealed many interesting facts. The shell type prosthesis in the left hip was only a half sphere. The edges of this partial sphere were eroding the acetabular cartilage at the extreme range of femur movement. This information resulted in changing the design of the prosthesis from a half sphere to approximately three-fifths of a sphere.

Figure 8

Dog #4. This was a small black and white dog wearing cage tag number 14. It had been used early in the studies to determine the best surgical approach to the coxofemoral joint. After this surgery, the hip had luxated and remained out of the acetabulum for two months. This would provide a similar type of injury to that seen in clinical practice. The surgical approach was very difficult due to extensive scar tissue and adhesions from the previous surgery. The femoral head was decalcified due to the presence of bacterial infection from the previous surgical invasion of the area. The acetabulum was filled in by soft fibrous tissue which was removed. The prosthesis was installed and the animal given a course of antibiotics. The prosthetic head luxated following surgery and could not be kept in place (Fig. 9). Three weeks later euthanasia was performed and this operation deemed a failure.

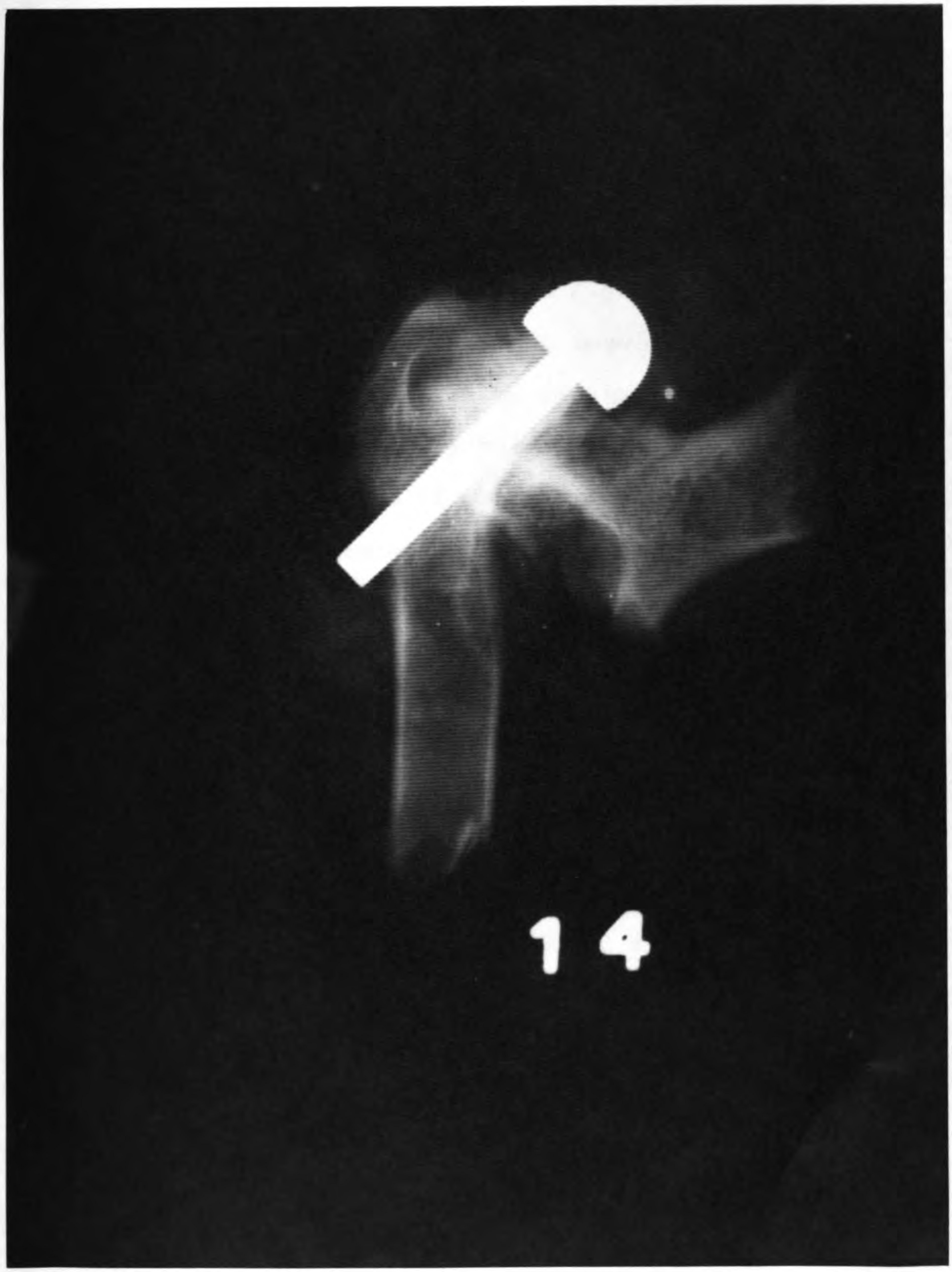


Figure 9

Cat #1. Arthroplasty of the left femoral head was performed on a six months old kitten. Weight bearing on the prosthesis was immediate as the animal had lost a forelimb by amputation some time previously. The kitten used the leg in a normal manner. The length of observation was three months. A postmortem examination on this animal was not possible.

Figure 10

Cat #2. A seven month old male cat was used for a double prostetic installation, the work being performed on successive days. The magnitude of such a surgical invasion of major weight bearing and propulsion tissues incapacitated the cat for about ten days. After that time the animal became ambulatory but had a lurch of the rump on walking. The necessity of confining most of these animals to their cage and the limited exercise and range of movement thus afforded, made it hard to evaluate return of functional use of these limbs.

The animal was euthanized three weeks following the surgery for the purpose of recovering the prosthetic devices. Gross pathology was absent in the surgical area.

Figure 11

Cat #3. This was a large old male cat that roamed the barn loft of the large animal clinic. Femoral head prosthetics of the Judet type were installed a week apart. The cat made a good recovery and was returned to his barn life to climb the bales of hay and straw in his hunting activities. He disappeared about one year later, fate unknown.

Figure 12

Cat #4. This cat was operated to correct a fracture of the femoral neck. It was done at the veterinary clinic at the University of Minnesota as part of the program of the American Animal Hospital Association. The animal was shipped to Michigan following the surgery and had good functional use of the leg. Surgical technique and skill had, by this stage, progressed to a point where it was felt that clinical cases could now be undertaken.

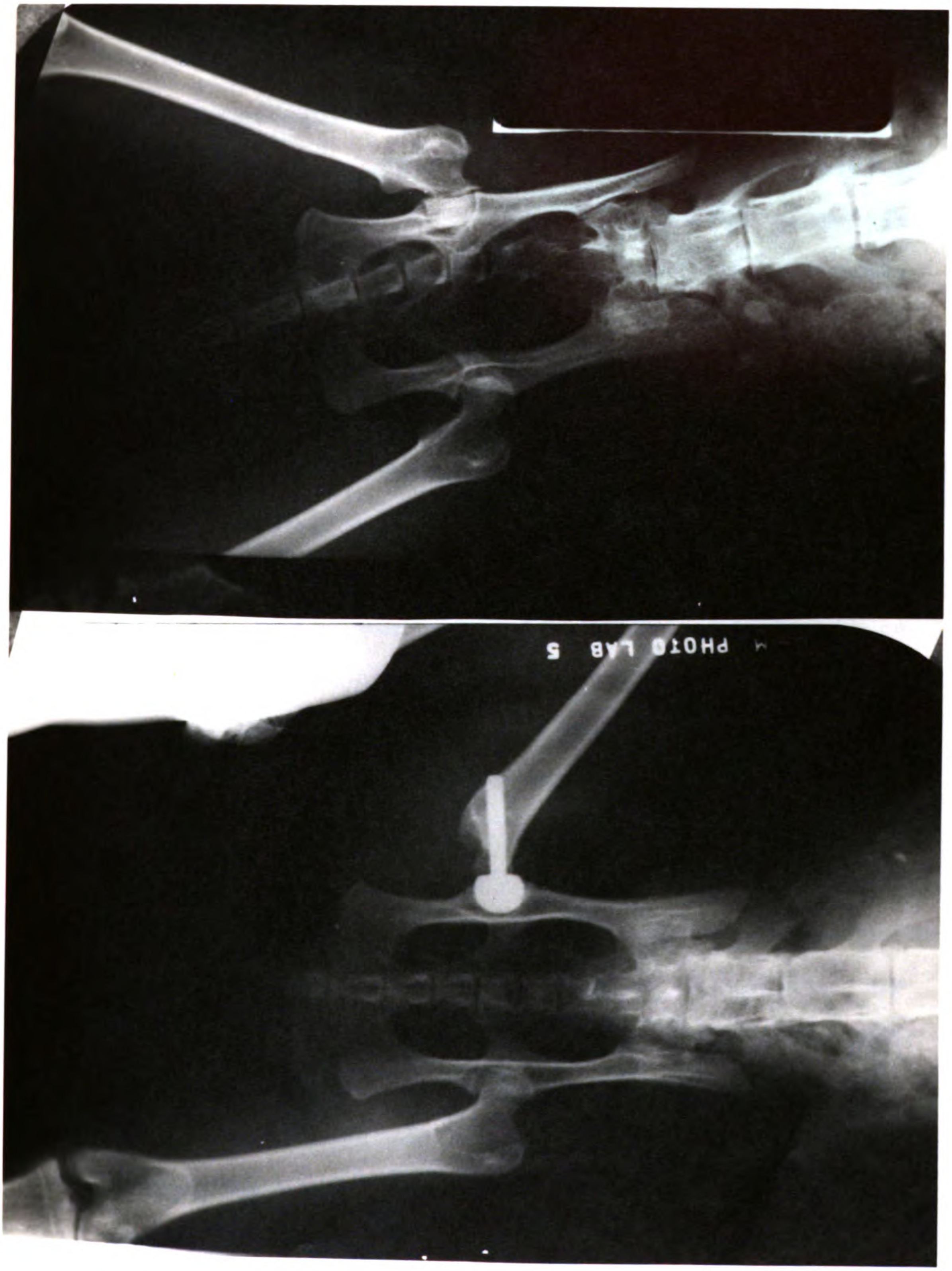


Figure 13

IV. DISCUSSION

Functional use of rear limbs altered by a femoral head prosthesis exceeded expectations. The positioning of the prosthesis in the femur was not proper in many of the cases and yet the animals used the limb. A dog or cat bears approximately two-thirds of its weight on the forelegs. The rear legs are mainly for propulsion. This weight distribution gives the veterinary surgeon a decided advantage over his human counterpart whose patients must bear all their weight during walking on one leg at a time.

The successful operations in this experiment occurred in those animals of a less active nature. Too great a load per unit of weight-bearing area produced bone necrosis and loosening of the prosthesis. The artificial head should fit the natural acetabulum for maximum load area of joint surface. The head should be in excess of a half-sphere, otherwise damage to the acetabular cartilage develops. The ideal prosthesis is one that is designed so that the stress is so distributed that the bone tolerates it by hypertrophy. In the Judet type used in this experimental work, the weight was placed on a small circular stem and in some cases loosened due to osteoporosis from the excess pressure. A three flanged stem might solve this difficulty. The Moore type with an intramedullary

stem should be tried. The head size and design were found to be very important. A head size too large causes necrosis on the rim of the acetabular cartilage. A half-sphere head resulted in cartilage damage and was changed to three-fifths of a sphere.

Lambert (1959), in his committee report, shows a complete reversal of prosthesis type in human hip surgery. The stem type (Judet) has been almost completely replaced by the intramedullary type (Moore, Thompson).

It was difficult in the discussion of the results of this new surgical procedure in experimental animals not to include the results of a number of clinical cases. Seven years have passed since the inception of this project. Many veterinary surgeons now invade the coxofemoral joint for a variety of surgical procedures. Variations of this surgical approach to the area have been described by other authors. Prostheses made of Vitallium and acrylic nylon have been used in place of stainless steel. Indications for the use of a femoral head prosthesis have narrowed down from the wide field of suggested applications to a procedure that is used if more conservative treatments fail. Enthusiasm in the use of hip prostheses should be restrained until a number in use over a long period of time justifies their continuance.

V. SUMMARY

An experimental replacement of the femoral head by a metal prosthesis was performed in four dogs and four cats. The surgical approach to the coxofemoral joint is described, along with a description of the replacement technique. Stainless steel, 18-8, type 303 was the material used for the prosthesis and its manufacture is described.

Functional use of the legs so altered was regained in seventy five percent of the cases. As surgical skill and technique progressed, the percentage of success increased. The longest period of observation on one animal was three years.

Post-mortem findings showed pathology due to the prosthetic device was present in excess of what was suspected from clinical observation.

Encouraging results in this experimental work suggest the possibility of restoring functional coxofemoral articulations in selected clinical cases.

VI. BIBLIOGRAPHY

Anderson, W. D., Schlotthauer, C. F., and Janes, J. M. Method for treatment of fractures of the femoral neck in the dog. An experimental study. J. A.V.M.A. 122:158-160, 1953.

Archibald, J., Brown, N. M., Nasti, E., and Medway, W. Open reduction for correction of coxofemoral dislocations. Vet. Med. 48:273-275, 1953.

Archibald, J., and Ballantyne, J. H. A practical prosthesis for the canine and feline femoral head. N. A. Vet. 34:496-498, 1953.

Bickel, W. H., and Babb, F. S. Cup arthroplasty of the hip. J. Bone & Joint Surg. 30-A:647-656, 1948.

Bohlman, H. R. Experiments with foreign materials in the region of the epiphyseal cartilage plate of growing bones to increase their longitudinal growth. J. Bone & Joint Surg. 11:365-384, 1929.

Bohlman, Harold R. Replacement reconstruction of the hip. A. J. Surg. 84:268-278, 1952.

Bottarelli, A. Dorsal approach to the coxofemoral joint. Clinical Veterinarian 61:407-422, 1938. (Abst. in N. A. Vet. 21:428, 1940)

Brown, Roger E. A surgical approach to the coxofemoral joint of dogs. N. A. Vet. 34:420-423, 1953.

Brown, Roger E. The experimental use of stainless steel femoral head prosthesis in normal dogs and cats. N. A. Vet. 34:423-428, 1953.

Colonna, Paul C. A new type of reconstruction operation for old un-united fractures of the femoral neck. J. Bone & Joint Surg. 19:945-947, 1937.

Gallie, W. E., and Lewis, F. I. Un-united fracture of the neck of the femur in the aged. J. Bone & Joint Surg. 22:76-80, 1940.

Gibson, A. Posterior exposure of the hip joint. J. Bone & Joint Surg. 32:183, 1950.

Gibson, Alexander and Williams, T. H. Changes in the femoral head underlying a Vitallium cup. J. Bone & Joint Surg. 33-B: 119-121, 1951.

Howe, William W. A study of the gross anatomy of the arteries supplying the proximal portion of the femur and the acetabulum. J. Bone & Joint Surg. 32-A: , 1950.

Jaenichen, Robert. Panel discussion. J. Bone & Joint Surg. 33-A:65, 1951.

Jenny, Jacques. Today's standard of fracture treatment in small animals. Proc. Book. A. V.M.A. 187, 1952.

Judet, Jean and Judet, Robert. The use of an artificial femoral head for arthroplasty of the hip joint. J. Bone & Joint Surg. 32-B:166-173, 1950.

Judet, Robert and Judet, Jean. Technique and results with the acrylic femoral head prosthesis. J. Bone & Joint Surg. 34-B:173-180, 1952.

Lambert, C. N. Chairman, Committee for study of femoral head prosthesis. Report. J. Bone & Joint Surg. 41-A:833-886, 1959.

Leadbetter, Guy W. Treatment for fracture of the neck of the femur. J. Bone & Joint Surg. 15-A:931, 1933.

Loomis, Lyon D. Internal prosthesis for the upper portion of the femur. J. Bone & Joint Surg. 32-A:944, 1950.

McBride, J. D. A femoral head prosthesis for the hip joint. J. Bone & Joint Surg. 34-A: 989, 1952.

McMurray, T. P. Fracture of the neck of the femur treated by oblique osteotomy. Br. Med. J. 1:330, 1938.

McNamara, W. L., Murphy, B., and Gore, W. A. Method of simultaneous fixation and decalcification of bone. J. of Lab. & Clin. Med. 25:874, 1940.

Miller, Malcolm. Guide to the Dissection of the Dog. Third edition. Ann Arbor. Edwards Bros. 1952.

Moore, Austin. Fracture of the hip joint. Treatment by extra-articular fixation with adjustable nails. Surg. Gynec. & Obst. 64:420-424, 1937.

Moore, A. T., and Bohlman, H. R. Metal hip joint. A case report. J. Bone & Joint Surg. 25:688, 1943.

Newman, P. H., and Scales, J. T. The unsuitability of polythene for moveable weight-bearing prostheses. J. Bone & Joint Surg. 33-B:392, 1951.

Patrick, James. Intracapsular fractures of the femur treated with a combined Smith-Peterson nail and fibular graft. J. Bone & Joint Surg. 31-A:67, 1949.

Peterson, L. T. The use of a metallic femoral head. J. Bone & Joint Surg. 33-A:65, 1951.

Phemister, Dallas B. Treatment of the necrotic head of the femur in adults. J. Bone & Joint Surg. 31-A:55-66, 1949.

Smith-Peterson, Marius N. Subperiosteal approach to the hip joint. A. J. Orth. Surg. 16:592, 1917.

Smith-Peterson, Marius N. Treatment of fractures of the neck of the femur by internal fixation. Arch. Surg. 23:715, 1931.

Smith-Peterson, Marius N. Arthroplasty of the hip: A new method. J. Bone & Joint Surg. 21: 269-288, 1939.

Smith-Peterson, Marius N. Approach to and exposure of the hip joint for mold arthroplasty. J. Bone & Joint Surg. 31-A:40-46, 1949.

Sodeman, William A. Pathologic Physiology: Mechanisms of disease. W. B. Saunders Co. 622, 1950.

Thompson, Vernon P., and Epstein, Herman C. Traumatic dislocation of the hip: A survey of 204 cases covering a period of 21 years. J. Bone & Joint Surg. 33-A:746-779, 1951.

Miller, Malcolm. Guide to the Dissection of the Dog. Third edition. Ann Arbor. Edwards Bros. 1952.

Moore, Austin. Fracture of the hip joint. Treatment by extra-articular fixation with adjustable nails. Surg. Gynec. & Obst. 64:420-424, 1937.

Moore, A. T., and Bohlman, H. R. Metal hip joint. A case report. J. Bone & Joint Surg. 25:688, 1943.

Newman, P. H., and Scales, J. T. The unsuitability of polythene for moveable weight-bearing prostheses. J. Bone & Joint Surg. 33-B:392, 1951.

Patrick, James. Intracapsular fractures of the femur treated with a combined Smith-Peterson nail and fibular graft. J. Bone & Joint Surg. 31-A:67, 1949.

Peterson, L. T. The use of a metallic femoral head. J. Bone & Joint Surg. 33-A:65, 1951.

Phemister, Dallas B. Treatment of the necrotic head of the femur in adults. J. Bone & Joint Surg. 31-A:55-66, 1949.

Smith-Peterson, Marius N. Subperiosteal approach to the hip joint. A. J. Orth. Surg. 16:592, 1917.

Smith-Peterson, Marius N. Treatment of fractures of the neck of the femur by internal fixation. Arch. Surg. 23:715, 1931.

Smith-Peterson, Marius N. Arthroplasty of the hip: A new method. J. Bone & Joint Surg. 21: 269-288, 1939.

Smith-Peterson, Marius N. Approach to and exposure of the hip joint for mold arthroplasty. J. Bone & Joint Surg. 31-A:40-46, 1949.

Sodeman, William A. Pathologic Physiology: Mechanisms of disease. W. B. Saunders Co. 622, 1950.

Thompson, Vernon P., and Epstein, Herman C. Traumatic dislocation of the hip: A survey of 204 cases covering a period of 21 years. J. Bone & Joint Surg. 33-A:746-779, 1951.

Miller, Malcolm. Guide to the Dissection of the Dog. Third edition. Ann Arbor. Edwards Bros. 1952.

Moore, Austin. Fracture of the hip joint. Treatment by extra-articular fixation with adjustable nails. Surg. Gynec. & Obst. 64:420-424, 1937.

Moore, A. T., and Bohlman, H. R. Metal hip joint. A case report. J. Bone & Joint Surg. 25:688, 1943.

Newman, P. H., and Scales, J. T. The unsuitability of polythene for moveable weight-bearing prostheses. J. Bone & Joint Surg. 33-B:392, 1951.

Patrick, James. Intracapsular fractures of the femur treated with a combined Smith-Peterson nail and fibular graft. J. Bone & Joint Surg. 31-A:67, 1949.

Peterson, L. T. The use of a metallic femoral head. J. Bone & Joint Surg. 33-A:65, 1951.

Phemister, Dallas B. Treatment of the necrotic head of the femur in adults. J. Bone & Joint Surg. 31-A:55-66, 1949.

Smith-Peterson, Marius N. Subperiosteal approach to the hip joint. A. J. Orth. Surg. 16:592, 1917.

Smith-Peterson, Marius N. Treatment of fractures of the neck of the femur by internal fixation. Arch. Surg. 23:715, 1931.

Smith-Peterson, Marius N. Arthroplasty of the hip: A new method. J. Bone & Joint Surg. 21:269-288, 1939.

Smith-Peterson, Marius N. Approach to and exposure of the hip joint for mold arthroplasty. J. Bone & Joint Surg. 31-A:40-46, 1949.

Sodeman, William A. Pathologic Physiology: Mechanisms of disease. W. B. Saunders Co. 622, 1950.

Thompson, Vernon P., and Epstein, Herman C. Traumatic dislocation of the hip: A survey of 204 cases covering a period of 21 years. J. Bone & Joint Surg. 33-A:746-779, 1951.

Venable, C. S. and Stuck, W. G. Results of recent studies and experiments concerning metals used in the internal fixation of fractures. J. Bone & Joint Surg. 30-A:247-249, 1948.

Venable, C. S., Stuck, W. G., and Beach, A. Effects on bone of the presence of metals: based of electrolysis: experimental study. Ann. Surg. 105:917-938, 1937.

Venable, C. S. Osteosynthesis in the presence of metals. Southern Med. J. 31:501-508, 1938.

Watson-Jones, Sir Reginald. _Fractures and Joint Injuries_. Vol. I & LL. Fourth Edition. The Williams and Wilkins Co. 1952.

Wertheimer, L. G. The sensory nerves of the hip joint. J. Bone & Joint Surg. 34-A:477-478, 1952.