# The Self-Locking Metal Hip Prosthesis

BY AUSTIN T. MOORE, M.D., COLUMBIA, SOUTH CAROLINA

*From The Moore Clinic, Columbia*

In 1940, in collaboration with Dr. Harold Bohlman of Baltimore, the author inserted the first Vitallium prosthesis to replace the upper portion of a femur. This was done after the removal of a questionably malignant tumor of the upper end of the femur in the intertrochanteric region [1]. The operation was successful. The patient gained approximately 75 per cent of normal function of the hip and lived for about two years before he died of a heart attack.

Some years later, the Judet brothers of Paris introduced a new stem type of endoprosthesis to replace the femoral head. This appeared to give satisfactory results, and variations of their model began to appear. The author was not impressed with the stem type of prosthesis and continued to search for an appliance which would promise better distribution and support of the normal stress load.

In 1950, with the assistance of the Professor of Engineering at the University of South Carolina and the Chief Engineer of the Austenal Laboratories, an intramedullary type of prosthesis was developed. A straight prosthesis with a solid stem was used at first and was applied through the anterior approach. This operation was found to be very difficult, and dislocation of the hip occurred in one or two patients following surgery. The prosthesis was modified in order to obtain the proper angle of the femoral neck on the shaft of the prosthesis, and the stem was fenestrated in order to lock the prosthesis in position and to allow better blood supply through the upper end of the femoral shaft. A suitable type of rasp was designed with which to seat the prosthesis correctly. A special posterior approach was developed by which the prosthesis could be inserted more easily than by the anterior approach. Through repetition of the operation, the incision was gradually shifted more posteriorly until eventually it became known as "the southern exposure" (Figs. 1-A and 1-B).

The approach is low on the buttocks, the lower glutaeus maximus fibers are separated, and none of the abductor muscles attached to the greater trochanter are divided (Figs. 2-A through 2-D). This preserves the strength and integrity of the hip, it obviates a postoperative abductor lurch and limp, and enables the patient to be up and about within a few days after surgery. The operation can be completed in twenty to thirty minutes, although the time scheduled is usually about forty-five minutes. There is very little blood loss and usually no shock. Precision is of utmost importance. Candidates for this surgery should be carefully selected. Operative risk and the degree of future function should be calculated. Accurate measurements and complete operative plans should always be made prior to surgery. At the time of operation, meticulous care should be taken in order to obtain a perfect fit of the prosthesis, with anatomical reconstruction as accurate as possible. End results are in direct proportion to the surgeon's preoperative planning and technical precision [2].

In the past six years this method has been used in a wide variety of cases; 159 operations have been performed on 153 patients. The results have ranged from excellent to poor, but with increasing experience we are convinced that a high percentage of satisfactory results can be obtained by this method. In fresh fractures of the neck of the femur there is always the question whether a prosthesis should be used. For years I have treated fractures of the femoral neck with multiple nailing, using the Moore adjustable nail [3]. For years I have stressed the importance of early perfect reduction, perfect fixation, and perfect postoperative protection until union has occurred. With this program,

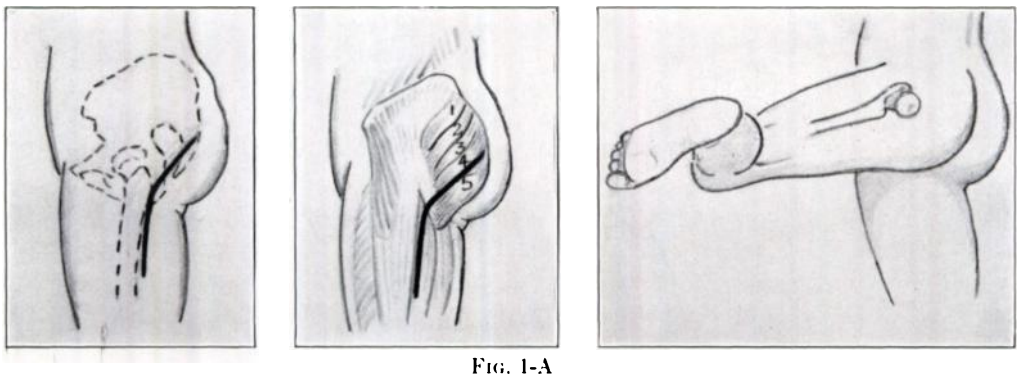

FIG. 1-A

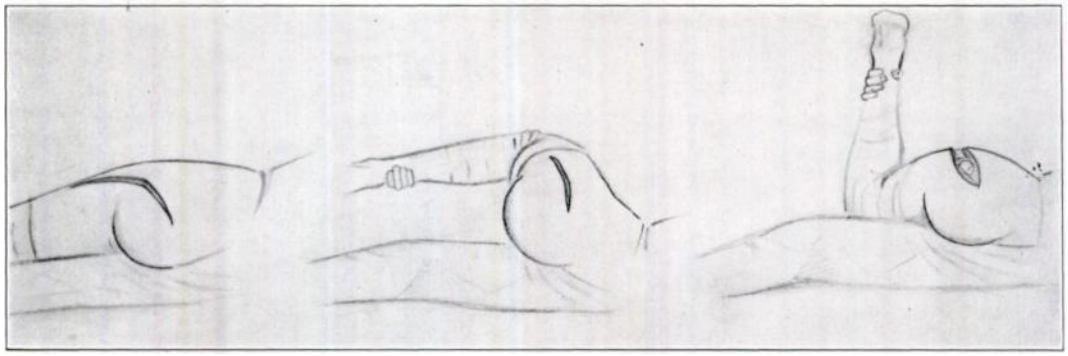

FIG. 1-B

Figs. 1-A and 1-B: The patient lies on his unaffected side. The incision is low on the buttocks and behind the greater trochanter. The thigh is flexed and internally rotated with the toe pointed toward the ceiling in order to dislocate the femoral head ("the southern exposure").

many excellent end results can be obtained. The poorer the technique, the poorer will be the end result. High, subcapital femoral-neck fractures and Pauwel type 3 fractures are the most difficult to reduce, but they will heal satisfactorily when treated by correct reduction, nailing, and well conceived postoperative protection. Fractures partially reduced may unite, but almost invariably there will be more or less aseptic necrosis of the femoral head. Traumatic arthritic changes in the hip joint take place in proportion to the degree of trauma and the skill with which the operation has been performed. Disturbance of the blood supply must be kept at a minimum.

When fractures of the femoral neck can be treated with satisfactory results by a method which preserves the natural head of the femur, there is no reason for the insertion of a prosthesis. When a better result can be obtained with artificial replacement of the head of the femur, there is every justification for the use of a prosthesis.

I have been orthopaedic surgeon at the Columbia State Hospital for the mentally ill for the past thirty years. There are approximately 7,000 beds in this institution, and a fairly large number of hip fractures occur in our patients. Many of these patients are aged, they are in poor physical condition for surgery, and they will not survive a long period of bed recumbency. Most of them are unable to cooperate with a program of postoperative protection following hip nailing. Results of hip nailing in this type of patient are poor. Patients who become bedridden require increased nursing and attendant care, and are, therefore a greater financial burden to the State. The insertion of a prosthesis can be done with no more risk to the patient than a hip-nailing operation, and frequently the risk and the shock are not so great. These factors indicate the value of the use of a prosthesis in treatment of fresh femoral-neck fractures in patients who are confined to a mental institution. Frequently the patients are up and about within a few days after surgery, and often no special nursing or attendant care is necessary.

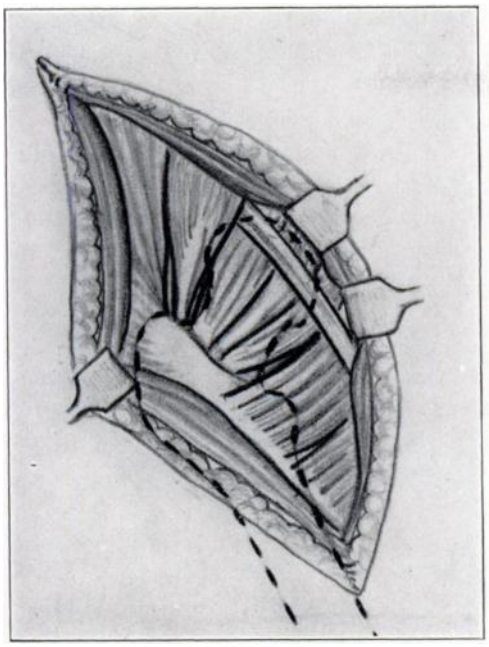

FIG. 2-A

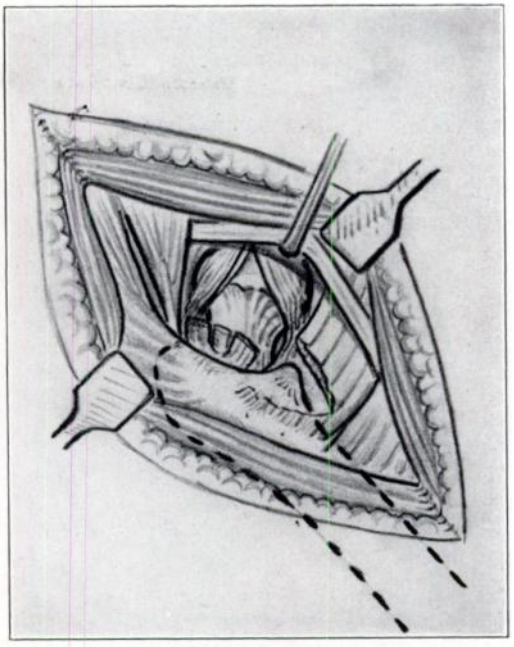

FIG. 2-B

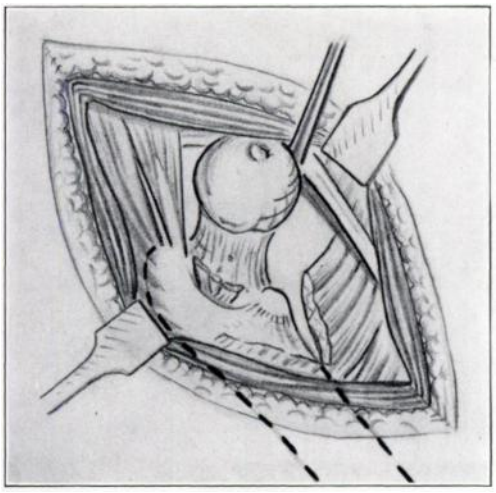

FIG. 2-C

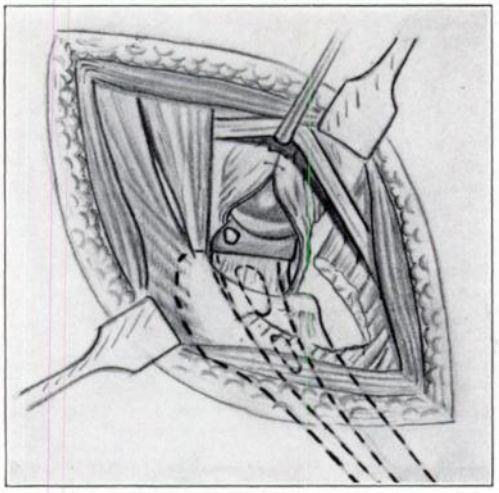

FIG. 2-D

Figs. 2-A through 2-D: The sciatic nerve is retracted and the branch to the posterior aspect of the hip capsule is divided. The attachment of the short extensor rotators, part of the quadriceps femoris, and possibly the piriformis are divided. The distal attachment of the hip-joint capsule is removed and the capsule is incised to the acetabulum in order to allow the femoral head to be removed. The edges of the wound fall back together and very little suture is required.

A prosthesis may be indicated in other types of fractures. In patients with Parkinson's disease, hemiplegia, or some other infirmity because of which they are unable to use crutches and cannot adequately protect themselves following a hip-nailing operation, the use of a prosthesis seems to be justifiable. The patient's age, weight, physical and mental fitness, social and economic status, domestic facilities, and psychological attitude are all factors to be considered when deciding whether or not a prosthesis should be used. It is not possible to lay down specific rules. Each patient is an individual problem. One of the best ways to arrive at a decision is to consider what the patient will be able to do and what can be expected if a prosthesis is not used. When this is compared with what may be expected from the insertion of a prosthesis, the decision can be readily made.

## TECHNIQUE OF OPERATION

Accurate measurements of the hip and the extremity should be made prior to the operation, and exact operative procedure should be planned so that the head and neck of the femur may be replaced as perfectly as possible. If the neck of the femur is lengthened by a prosthesis which is too large, the hip-joint capsule may be stretched and there will be residual pain. If the size of the head of the prosthesis is too small, there will be degenerative changes in the acetabulum with consequent "wandering acetabulum", traumatic arthritis of the hip, or arthrokatadysis. In order to distribute the stress evenly

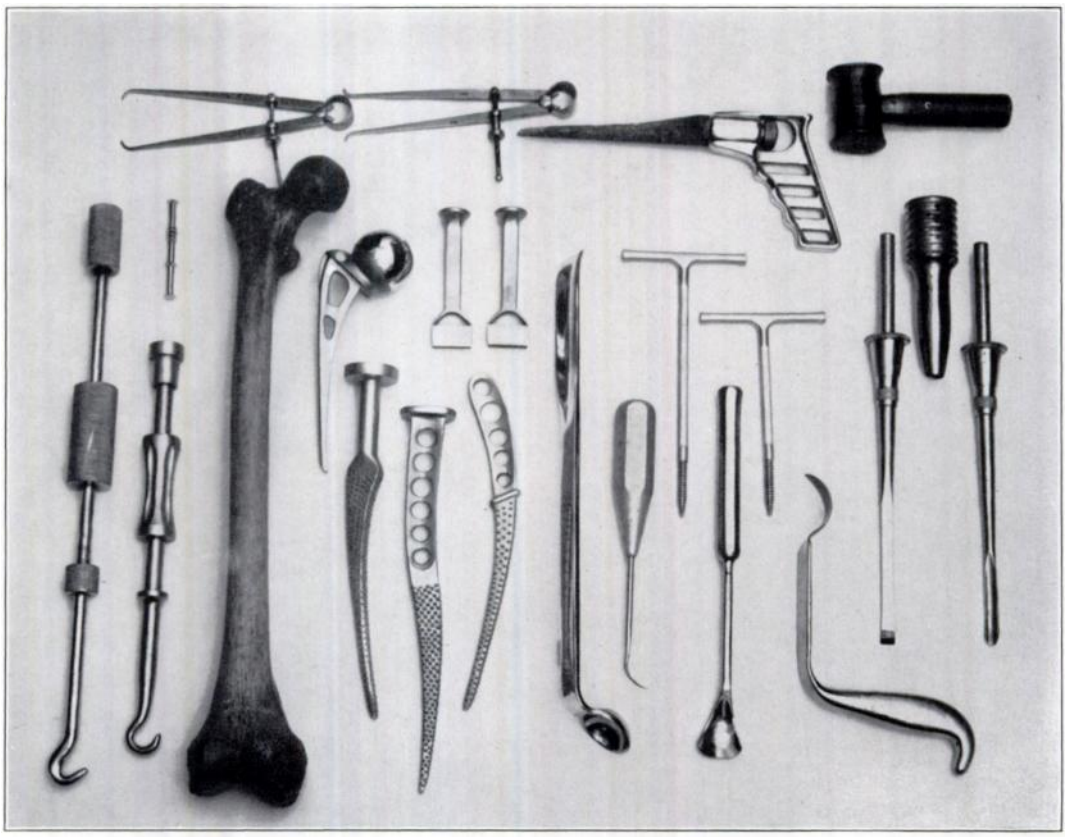

FIG. 3

Special instruments designed for use in inserting the prosthesis.

Top row: outside and inside calipers for measuring the head of the femur and the acetabulum; bone saw and heavy bronze mallet.

Below, at the left of the femur: driver extractors and a small measuring rod, marked to measure one inch, one and one-half inches, one and five-eighths inches, one and three-fourths inches, two inches, and two and one-eighth inches. With this rod strapped to the patient's thigh and with the use of calipers, exact dimensions can be calculated for a prosthesis of perfect fit. The purpose of the instruments at the right of the femur is obvious.

it is important that the head of the prosthesis fit perfectly. At the time of surgery the five different sizes of the prosthesis should be at hand.

The patient lies on his side with the injured hip uppermost; the thigh on the injured side is flexed to approximately 45 degrees. The incision is begun low on the buttocks, about two inches distal to and toward the outer side of the posterior inferior spine of the ilium. It courses downward and outward just beneath the greater trochanter and extends along the outer side of the thigh about four inches below the greater trochanter. The use of the posterior incision avoids pressure or tension necrosis which may occur when the incision is made directly over the greater trochanter. The fascia lata just be-

neath the greater trochanter is incised, and this incision is continued upward, dividing the aponeurotic insertion of the glutaeus maximus. It is easy, then, manually to separate the lower fibers of the glutaeus maximus upward to the point where the superior gluteal vessels are encountered. The glutaeus maximus fibers which have been separated are about one and a half inches above the lower border of this muscle. This exposure is made with practically no bleeding; wound towels are applied and the patient's thigh is flexed further, toward a right angle; the upper fibers of the glutaeus maximus are easily held

FIG. 4

Prosthesis models used from 1939 to 1951. At the left is a femur with an early type of prosthesis which was inserted in 1939 by Moore and Bohlman [1]. The specimen was removed at autopsy, two and a half years after insertion. The straight-stem prosthesis was used in a few early cases. The prosthesis with oval-shaped fenestrations was used until recently. The openings were slightly enlarged and flattened at their upper margins to improve stress-bearing surfaces.

above the greater trochanter with a retractor. The sciatic nerve lies fully exposed in the lower part of the wound. It is retracted medially; and, as it is dissected upward, the small branch of this nerve extending to the external rotators of the hip and to the posterior capsule of the hip joint is easily identified and resected. Resection of this nerve is thought to be of benefit in relieving postoperative pain. In some patients the distal insertion of the lower fibers of the glutaeus maximus may have to be partially divided for ample exposure. The fatty tissue behind the lower portion of the capsule of the hip joint in the intertrochanteric region is removed. The insertions of the short external rotators, the gemelli, and the obturator internus are divided, and as these muscles are retracted the posterior aspect of the hip capsule is exposed. Occasionally it may be necessary to divide the inser-

TABLE I

STATISTICAL TABLE OF FIFTY-FIVE PATIENTS WITH FOLLOW-UP RESULTS OF TWO YEARS OR MORE *

| | Patient | Result | Age | Pain | Diagnosis | Walk | | Work | Motion (*Per cent*) | Operation | Prosthesis Size (*Inches*) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Limp | Support | | | | |
| 1. | Mrs. T.P. | Excellent | 74 | None | Acute fracture; Parkinson's disease | Moderate | Cane | Housewife | 100 | 10-30-53 | 1⅞ |
| 2. | Mrs. A.F.K. | Excellent | 72 | None | Acute fracture | Slight | Cane | Housewife | 100 | 7-7-54 | 1⅞ |
| 3. | Mrs. G.R. | Excellent | 42 | None | Old fracture; aseptic necrosis | Slight | None | Housewife | 100 | 9-25-53 | 2 |
| 4. | Mrs. L.K.P. | Excellent | 61 | None | Acute fracture | Slight | None | Mill worker | 100 | 6-20-53 | 1⅞ |
| 5. | Mr. F.T. | Good | 62 | Slight | Old fracture-dislocation; arthritis | Moderate | Cane | Farmer | 100 | 6-12-53 | 2 |
| 6. | Mr. E.W. | Excellent | 40 | None | Arthritis; old osteochondritis dissecans with aseptic necrosis | None | None | Farmer | 100 | 5-8-53 | 2⅛ |
| 7. | Mrs. H.Z. | Excellent | 83 | Slight | Acute fracture | None | None | Housewife | 100 | 8-4-53 | 1⅞ |
| 8. | Mr. D.M. | Fair | 17 | Slight | Old septic arthritis | Severe | Crutch | Student | 70 | 7-8-52 | 2 |
| 9. | Mr. J.R.W. | Fair | 63 | Slight | Degenerative arthritis | Moderate | Crutch | Farmer | 100 | 5-3-54 | 2⅛ |
| 10. | Mrs. J.R.K. | Excellent | 55 | None | Fracture, non-union | Slight | Cane | Housewife | 100 | 5-27-52 | 1⅞ |
| 11. | Mrs. W.H.C. | Excellent | 39 | None | Old fracture, non-union | None | None | Office work | 100 | 7-16-53 | 1¾ |
| 12. | Mrs. L.S. | Excellent | 75 | None | Acute fracture | None | None | Housewife | 100 | 12-14-51 | 1⅞ |
| 13. | Mr. L.C. | Good | 89 | None | Acute fracture | Severe | Walker | Retired | 75 | 12-18-53 | 2⅛ |
| 14. | Mrs. C.M. | Good | 70 | Slight | Acute fracture | Slight | Cane | Housewife | 85 | 12-24-52 | 1⅞ |
| 15. | Mr. H. McC | Excellent | 29 | None | Gun shot; arthritis | Slight | Cane | Farmer | 75 | 3-5-54 | 2 |
| 16. | Dr. S.R.G. | Good | 46 | None | Old fracture; non-union | Moderate | Cane or crutch | Physician | 60 | 3-20-51 | 2⅛ |
| 17. | Miss E.T. | Good | 52 | Slight | Old fracture-dislocation; aseptic necrosis; arthritis | Slight | Cane | Secretary | 100 | 2-24-53 | 1¾ |
| 18. | Mrs. D.S. | Excellent | 50 | None | Old fracture with aseptic necrosis | Slight | None | Housewife | 100 | 7-1-52 | 1⅞ |
| 19. | Mrs. J.F. | Fair | 50 | Slight | Arthritis | Moderate | None | Housewife | 60 | 5-7-52 | 1⅞ |
| 20. | H.M. | Poor | 22 | Slight | Marie-Strümpell arthritis | Moderate | Crutch | Student | 33⅓ | 10-12-51 | 1⅞ left |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20-A. | H.M. | Poor | 22 | Slight | Marie-Strümpell arthritis | Moderate | Crutch | Student | 33⅓ | 10-26-51 | 1⅞ right |
| 21. | Mrs. A.W. | Poor | 52 | Slight | Old fracture with non-union | Moderate | Cane | Beautician | 75 | 7-25-51 | 1⅞ |
| 22. | Mr. T.C.A. | Poor | 47 | Severe | Marie-Strümpell arthritis | Severe | Wheel chair | | 33⅓ | 5-11-54 | 2 right |
| 22-A. | Mr. T.C.A. | Poor | 47 | Severe | Marie-Strümpell arthritis | Severe | Wheel chair | | 15 | 1-25-55 | 2 left |
| 23. | Mr. L.L. | Good | 31 | None | Generalized traumatic arthritis; Naden-Reith prosthesis removed | Slight | Cane | Office work | 100 | 3-18-55 | 1¾ |
| 24. | Mr. J.D.L. | Fair | 44 | Mild | Traumatic arthritis | Moderate | Crutch | Watchmaker | 50 | 4-6-55 | 2⅛ |
| 25. | Mrs. E.S. | Fair | 66 | Slight | Acute fracture | Slight | Crutch | Housewife | 100 | 12-30-51 | 1⅞ |
| 26. | Mrs. G.P. | Good | 50 | Slight | Degenerative arthritis; cup was removed | Moderate | Cane | Housewife | 100 | 10-7-54 | 1⅞ |
| 27. | Mr. L.C. | Excellent | 59 | Slight | Arthritis, bilateral; to return for operation on other hip | Moderate | Crutch | Retired | 75 | 10-29-55 | 2⅛ |
| 28. | Mrs. M.H. | Good | 27 | None | Old infectious arthritis | Slight | Cane | Housewife | 75 | 8-17-54 | 1⅞ |
| 29. | Mrs. G.P. | Excellent | 70 | None | Fracture, non-union | Slight | None | Retired | 100 | 6-1-54 | 1¾ |
| 30. | Mr. F.W.G. | Good | 64 | Slight | Arthritis | Moderate | Cane | Retired | 75 | 10-20-54 | 2 left |
| 30-A. | Mr. F.W.G. | Good | 64 | Slight | Arthritis | Moderate | Cane | Retired | 65 | 11-9-54 | 2 right |
| 31. | Mrs. L.M. | Excellent | 51 | None | Arthritis | Slight | None | Mill worker | 100 | 7-27-54 | 1⅞ |
| 32. | Mrs. E.P. | Fair | 72 | Slight | Bilateral fracture, non-union | Moderate | Crutches | None | 100 | 11-5-54 | 1¾ |
| 33. | Mrs. F.McK | Good | 69 | Slight | Old fracture with aseptic necrosis | Moderate | Cane | Retired | 100 | 11-23-54 | 1¾ |
| 34. | Mrs. I.O. | Fair | 43 | Slight | Arthritis; old congenital dysplasia, bilateral | Moderate | Crutch | None | 100 | 1-4-55 | 1⅞ |
| 35. | Mrs. E.D. | Excellent | 56 | None | Fracture with non-union | None | None | Housewife | 100 | 11-17-53 | 1¾ |
| 36. | Mrs. C.G. | Good | 62 | Slight | Fracture with non-union; Parkinson's disease | Moderate | Cane | None | 100 | 5-19-53 | 1⅞ |
| 37. | Mr. L.H. | Good | 72 | Slight | Fracture with non-union | Slight | Crutch | None | 75 | 2-24-53 | 1⅞ |

TABLE I *(continued)*

| | Patient | Result | Age | Pain | Diagnosis | Walk | | Work | Motion (*Per cent*) | Operation | Prosthesis Size (*Inches*) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Limp | Support | | | | |
| 38. | Mrs. J.R. | Fair | 53 | Slight | Old slipped epiphysis with arthritis | Slight | Crutch | None | 50 | 5-18-51 | 1⅞ |
| 39. | Mrs. A.E. | Good | 77 | None | Old fracture with non-union | Moderate | None | Retired | 75 | 11-21-52 | 1¾ left |
| 39-A. | Mrs. A.E. | Good | 77 | None | Acute fracture | Moderate | None | Retired | 75 | 6-20-53 | 1¾ right |
| 40. | Miss V.McC | Good | 18 | Slight | Rheumatoid arthritis; cup arthroplasty | Moderate | Cane | Secretary | 20 | 4-11-51 | 1⅝ left |
| 40-A. | Miss V. McC | Good | 18 | Slight | Rheumatoid arthritis; cup arthroplasty | Moderate | Cane | Secretary | 10 | 3-7-52 | 1⅝ right |
| 41. | Mrs. B.K. | Excellent | 76 | None | Fracture with non-union | Slight | Cane | Housewife | 100 | 1-15-54 | 1⅞ |
| 42. | Mr. W.M. | Fair | 16 | Moderate | Slipped epiphysis | Moderate | Crutch | Light work | 65 | 8-7-53 | 2 |
| 43. | Mrs. A.A. | Good | 62 | Slight | Fracture with non-union | Slight | Cane | Housewife | 100 | 2-2-54 | 1⅞ |
| 44. | Mrs. D.C. | Good | 50 | Moderate | Old fracture; aseptic necrosis | Slight | Cane | Housewife | 90 | 4-25-52 | 1¾ |
| 45. | Mr. B.T. | Fair | 16 | Moderate | Traumatic arthritis | Slight | Crutch | Light work | 75 | 3-12-51 | 2 |
| 46. | Mr. C.C. | Failure | 46 | Moderate | Old osteomyelitis | Severe | Crutch | Light work | 60 | 2-8-52 | 1⅞ |
| 47. | Mr. L.S. | Good | 15 | Mild | Slipped epiphysis, bilateral | Moderate | Cane | Light work | 75 | 10-6-53 | 1⅞ |
| 47-A. | Mr. L.S. | Good | 15 | Mild | Slipped epiphysis, bilateral | Moderate | Cane | Light work | 75 | 10-29-53 | 1⅞ |
| 48. | Mrs. G.H. | Good | 63 | Mild | Fracture, non-union | Slight | Cane | Light work | 100 | 4-3-53 | 1¾ |
| 49. | Mr. H.H. | Good | 66 | Mild | Fracture, aseptic necrosis | Slight | Cane | Light work | 100 | 4-28-52 | 1⅞ |
| 50. | Mrs. S.P. | Excellent | 65 | None | Fracture with non-union | Slight | None | Housewife | 100 | 5-14-53 | 1¾ |
| 51. | Mrs. E.C. | Good | 81 | None | Acute fracture | Slight | Cane | Retired | 100 | 3-10-54 | 1¾ |
| 52. | Mr. D.T. | Excellent | 62 | None | Acute fracture | None | None | Farmer | 100 | 4-18-52 | 1⅞ |
| 53. | Mrs. C.B. | Good | 54 | Moderate | Old fracture with non-union | Slight | Cane | Light work | 75 | 1-17-51 | 1⅞ |
| 54. | Mrs. H.K. | Good | 71 | Moderate | Old fracture with aseptic necrosis | Slight | Cane | Light work | 100 | 4-7-52 | 1⅞ |
| 55. | Mr. G.A. | Excellent | 21 | None | Slipped epiphysis | Slight | None | Light work | 100 | 10-12-54 | 2 |

* In this table the length of follow-up in each case is the time between the date of operation and October 19, 1956, when this study was completed.

tion of the piriformis or the upper third of the insertion of the quadratus femoris. The hip capsule is incised in line with the long axis of the femoral neck upward to the acetabular margin. The distal insertion of the capsule into the posterior portion of the femoral neck is separated from its attachment until a full view of the lower posterior portion of the neck is obtained. The distal capsular attachment is stripped downward to expose completely the lower and under surface of the femoral neck. The lesser trochanter, an important landmark, can now be readily identified. The only blood vessel that may need to be ligated is the posterior circumflex artery; usually ligation of this vessel is not necessary. There should be practically no bleeding. Dislocation of the femoral head from the socket is usually accomplished with little difficulty. The thigh is flexed to a full right angle and adducted, and the leg is turned into internal rotation at a right angle, with the knee flexed to 90 degrees. In this position the foot of the patient points directly upward toward the ceiling. The surgeon should be careful not to apply excessive force in this manipulation, for it is possible to fracture the shaft in attempting to dislocate the femoral head. Usually a long screw with a special T type handle is placed in the femoral head in order to pull and lever the head out of the socket, or a small skid can be used for this purpose. The neck of the femur is cut with a saw one-half to three-quarters of an inch above the lesser trochanter. This cut must be made in exactly the right plane to ensure the perfect fit of the prosthesis and to incline it forward in order to preserve the normal anteversion of approximately 20 degrees. In instances when it is difficult to displace the femoral head from the acetabulum, the neck of the femur may be divided and the head subsequently removed. The ligamentum teres, if present, is divided so that no stump remains, and the acetabulum is carefully inspected. Usually I do not remove any of the acetabular cartilage or attempt to deepen the socket. In exceptional cases, osteophytes or overgrown bone about the acetabular margin may be removed. Extreme care must be exercised in fitting the prosthesis. The shaft of the femur is not hollowed out, for this would result in a loose fit, but special chisels and a special rasp are used to remove bone from the shaft, a little at a time, so that finally, when the stem of the prosthesis is driven into place, the fit is accurate and tight. Before the final seating of the prosthesis, bits of cancellous bone removed from the femoral neck and the upper end of the femoral shaft are placed in the fenestrations of the prosthesis. These pieces of cancellous bone are actual bone grafts; they grow and become increasingly dense, locking the prosthesis in place and adding strength to withstand the stress of weight-bearing. Accurate measurements with calipers are made before deciding on the size of the head of the prosthesis to be used, and always the head is placed in the acetabulum for a trial fit before the stem is inserted into the shaft of the femur. Finally, the metallic head is placed in the acetabulum. This should be done without too much force, for too tight a fit will stretch the hip capsule and cause pain; the femoral shaft may even be broken if a fit approximating the natural cannot be obtained. In order to relax the quadriceps femoris and to relieve tension in the hip, the knee joint is extended before applying the traction necessary to replace the femoral head. The femoral head is not replaced by manipulating the extremity, but rather it is pulled downward over the acetabulum and the surgeon gently forces it into the acetabulum. The head of the prosthesis is guided into place by manipulating the extremity from the position of internal rotation into the neutral and anatomical position, and the thigh is brought down from the flexed position into complete extension. In this position the muscles and the capsule of the hip joint fall back together, and only a few deep sutures are necessary to close the wound. The skin is closed loosely with interrupted silk sutures. As the patient lies in bed with the limb extended and externally rotated, the tissues are brought closer together and there is no danger of dislocation of the prosthesis which might occur when an anterior incision is used. With this procedure, we have not had a single case of dislocation of the prosthesis.

It is surprising how often the large size (two inches or two and one-eighth inches)

TABLE II

COMPLICATIONS IN 159 OPERATIONS

| | | |
|---|---|---|
| In the first six patients, the early straight-stem prosthesis was used, inserted by the anterior approach. | | |
| Dislocations | | 2 |
| Fracture of the rim of the acetabulum | | 1 |
| In the subsequent 153 patients, the present prosthesis was used with the improved operative technique | | |
| Operative deaths: | | 3 |
| Surgical shock | 1 | |
| Cardiac arrest | 1 | |
| Pneumonia, postoperatively | 1 | |
| Wounds infections, superficial | | 3 |
| Wound infections, severe | | 1 |
| Old osteomyelitis with recurrent infection two years after surgery; prosthesis removed | | 1 |
| Prosthesis temporarily loosened in shaft (One was an early model short-stem prosthesis. All relieved by cessation of weight-bearing.) | | 3 |
| Patients with satisfactory result but with unexplainable pain | | 2 |

prosthesis can be used. The prosthetic head size commonly used is one and seven-eighths inches (Tables I and V).

By stripping the muscle attachment from the upper end of the femoral shaft when necessary, this exposure can be used satisfactorily for almost all operations about the hip joint. Following surgery the patient is allowed to move about, with caution, in bed. No external support or traction is necessary. Within a few days he may be up and about on crutches. He may leave the hospital approximately ten days after surgery. Weight-bearing is restricted during the first six months and gradually increased as roentgenograms reveal increasing bone density about the prosthesis. The patient returns for a careful check-up study and a roentgenographic examination every two months for a year following the operation. I insist on six-month or yearly follow-up examinations of all of our patients; they are cautioned that they should carry a cane and be careful in the use of the hip the balance of their lives.

## RESULTS

A total of 159 operations have been performed. A statistical study of end results two or more years after operation is reported in Table I.

The results have been proportional to the judgment which was used in selecting the patients and to the operative technique and follow-up care. During two of the early

TABLE III

RESULTS IN FIFTY-FOUR SOUTH CAROLINA STATE HOSPITAL PATIENTS ALL WITH FRACTURE OF THE FEMORAL NECK

| | | |
|---|---|---|
| Operative deaths: | | 2 |
| Surgical shock | 1 | |
| Pneumonia one week after surgery | 1 | |
| Died later: Senile changes; cardiovascular disease | | 9 |
| Walking, no complaint | | 30 |
| Walking, with complaint of pain | | 1 |
| Wheel chair | | 4 |
| Dismissed from hospital in good mental and physical condition | | 8 |
| Wound infection, superficial | | 2 |
| Wound infection, severe | | 1 |

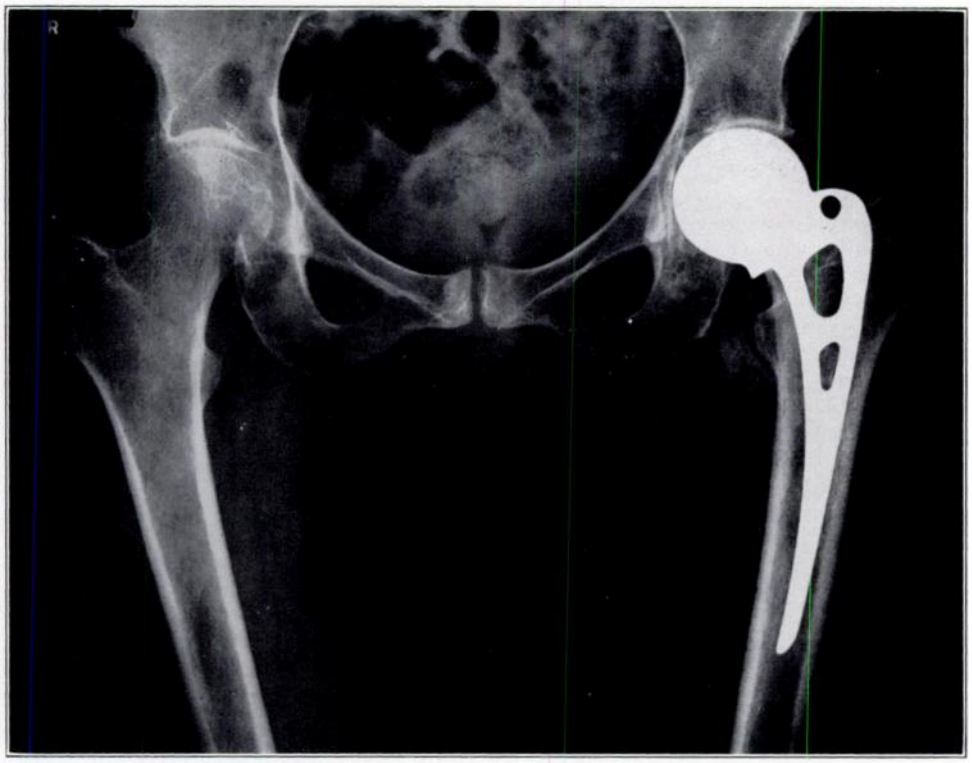

FIG. 5

Typical high capsular fracture in a mentally ill patient seventy-two years old. The patient was up and about a few days after the operation. No nursing care was necessary. Note the normal outline of the upper end of the femur; there was no shortening. This is the latest type of prosthesis, the proximal fenestrations flattened to sustain weight-bearing stress. The upper surfaces of the fenestrations are flattened, not oval-shaped as formerly, for the same purpose.

operations dislocation occurred when the patient's hip was in the adducted position. This was due to the straight type of prosthesis which was used at that time and to the fact that in the anterior approach to the hip the capsule of the hip joint was detached from the acetabular rim. No dislocation occurred with the present technique. No fracture of the femoral shaft occurred during operation. In the early cases, the patient's extremity was placed in traction and abduction following surgery or the thighs were held apart by means of a special brace. All this has been obviated by the low posterior approach. With the present approach I do not believe it would be possible to dislocate the hip without anaesthesia.

In some of the early patients when the capsule of the hip joint was divided at its acetabular attachment, excessive new-bone formation subsequently developed which limited abduction and produced pain by the pinching of the trochanteric region against this roughened acetabular rim. With the low posterior approach to the hip joint, the acetabular margin is never disturbed. The joint capsule is incised in line with the long axis of the neck of the femur, and the capsule is detached from its distal insertion in the intertrochanteric region. Two of the early operations resulted in complete failure. One patient died of cardiac arrest on the operating table. Several patients died at varying times after the operation, but this mortality rate was no higher than that in similar surgery. There have been three superficial infections but no deep infected wounds. It has been necessary only once to remove the prosthesis. In this instance, the patient had had osteomyelitis of the hip, and the prosthesis was used with mental reservation. The wound healed *per primam,* but two years after surgery infection developed which was considered a

TABLE IV

DIAGNOSIS

| | |
|---|---|
| Acute fracture of the femoral neck | 11 |
| Old fracture with non-union | 13 |
| Old fracture with aseptic necrosis | 5 |
| Osteo-arthritis | 5 |
| Old slipped epiphysis with osteo-arthritis | 4 |
| Old traumatic dislocation, osteo-arthritis, and aseptic necrosis | 3 |
| Traumatic arthritis | 3 |
| Degenerative arthritis | 1 |
| Old congenital dysplasia with osteo-arthritis | 1 |
| Osteochondritis dissecans with traumatic arthritis | 1 |
| Gunshot wound with arthritis | 1 |
| Rheumatoid arthritis (cup was removed) | 1 |
| Degenerative arthritis (cup was removed) | 1 |
| Marie-Strümpell arthritis | 2 |
| Old septic arthritis | 2 |
| Old osteomyelitis | 1 |
| Total | 55 |

flare-up of the osteomyelitis. There have been no cases of arthrokatadysis and no instances in which the prosthesis migrated downward into the femoral shaft. In three patients there appeared to be some motion of the prosthetic stem in the medullary canal, but this was relieved by cessation of weight-bearing and the use of crutches.

FIG. 6

In one patient a short-stem prosthesis was used. Definite motion of the stem in the shaft developed; this demonstrated the necessity of a long stem. An audible click could be heard and the patient complained of pain. The condition was controlled by the use of crutches or a cane for support. With increasing strain of weight-bearing there was growing discomfort in the hip, and when weight-bearing was limited the pain was relieved. Two patients complained of pain for which no reason was found. Both of these patients were highly nervous, emotionally unstable women. I reoperated on the hip of one of them and dislocated the head of the prosthesis from the acetabulum in an effort to determine the reason for her pain. No pathological condition was found. Following surgery she said that she was immediately relieved of the pain. She gained in weight and in appearance, but

Fig. 6: Roentgenogram of a femur which was removed from a patient who died a year and a half after surgery. It shows clearly the bone reaction about the prosthesis in areas where stress is applied. There is increased density under the collar, along the calcar femorale, in the fenestrations (especially their upper borders), along the outer aspect of the lower half of the stem, and under and about the tip of the stem. Microscopic examination of sections cut from this specimen clearly show this bone reaction.

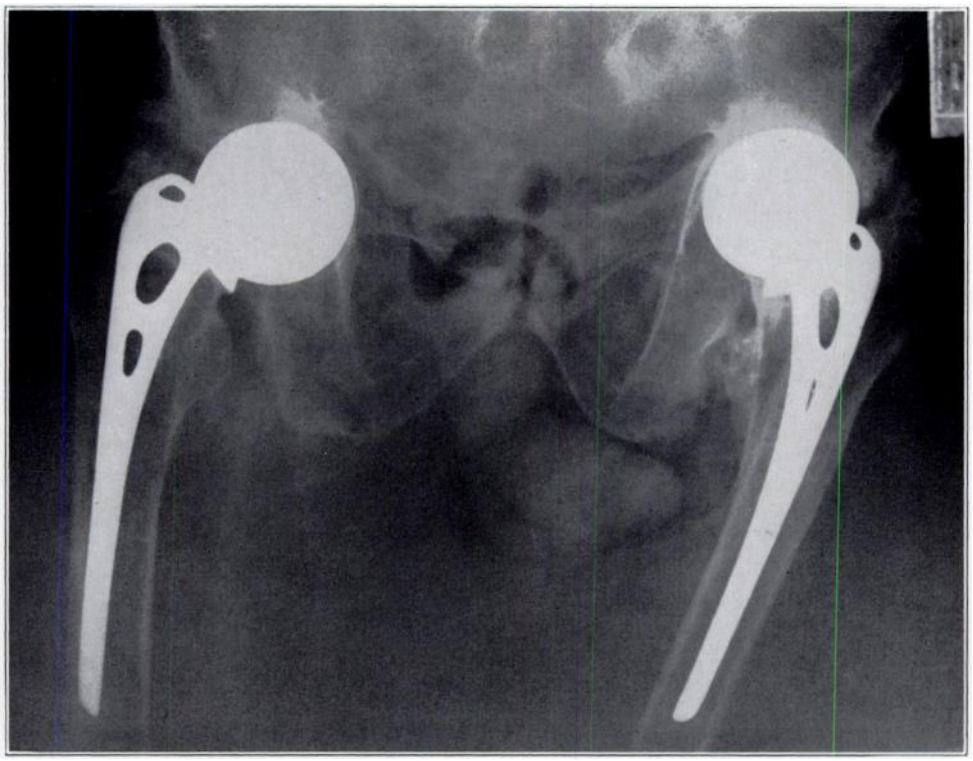

FIG. 7

Patient T.C.A. The diagnosis was advanced Marie-Strümpell arthritis of the spine and hips. The right hip was operated upon May 11, 1954, by Dr. J. S. Barr, of Boston, Massachusetts, who also performed osteotomy of the spine. The patient's left hip was operated upon January 25, 1955, by the author. There are six patients with bilateral hip prostheses in the series.

after a few weeks the pain recurred, and when she was last examined, she continued to complain of discomfort. In no patient has there been evidence of infection, corrosion, or any irritative or malignant change caused by the contact of Vitallium with bone (Table II).

Most of the results are satisfactory, some are excellent. I am confident that they have been more successful than could be expected from any other reconstructive or arthroplastic procedure. With careful control, the prosthesis may give satisfactory service throughout a patient's lifetime. In general, the operation is more suitable for older patients than for young ones. Years of experience will be necessary before positive statements can be made.

## STATISTICAL SUMMARY OF TWO YEARS' OR MORE FOLLOW-UP

In the past six years we have fitted 153 patients with the Moore prosthesis. Six of these patients have been operated upon bilaterally. There was a husband and wife in the series. In one patient a cup was allowed to remain in one side and the prosthesis was inserted in the other. In several instances a cup or other type of prosthesis was removed and a Moore prosthesis inserted.

Of the 153 patients, fifty-four were patients in the Columbia State Hospital. All of these patients had fractures of the femoral neck. The patients were in varying stages of mental illness, and in many instances their general health was poor. Control of these patients was impossible. Surgery was planned in an effort to minimize nursing and attendant care. The results have been generally satisfactory, and economically, as well as in increased comfort to the patient, the procedure has been justified. The problem is still under study (Table III).


FIG. 8

FIG. 9

Fig. 8: Patient Mrs. W.H.C. Follow-up examination three and a half years after operation showed an excellent result with practically normal function. Roentgenograms showed anatomical reconstruction and increased bone density where the stress load was carried. These changes are seen in the roentgenogram under the collar and tip of the prosthesis, about the stem, along the calcar femorale, and in the upper weight-bearing portions of the fenestrations. This is in accordance with Wolff's law. The prosthesis literally becomes part of the living bone.

Fig. 9: Dried specimen. This femur was removed at autopsy about a year after the insertion of the prosthesis. Bone grafts are clearly seen in the fenestrations and there are areas of increased density about the prosthesis. (Courtesy of Dr. J. W. Fredette, Pittsburgh, Pennsylvania.)

Of the remaining ninety-six cases, fifty-five patients underwent sixty-one operations and have been followed for two to six years.

There were thirty-five females and twenty males in this group.

The ages of the patients varied from fifteen years to eighty-nine years. The majority were between sixty and seventy years old.

There were six patients between fifteen and twenty years of age. Treatment of these young patients was part of the State Crippled Children's Program. Four of the six patients were severely crippled with slipped epiphyses. The prosthesis was inserted bilaterally in one of the four. Another was a young girl severely crippled with generalized arthritis and ankylosis of both hips. Previously, bilateral cup arthroplasty had been performed. Pain was relieved by substituting prostheses for the cups. When she was seen six years after surgery, she had improved remarkably.

These operations upon young patients were done as salvage procedures. So far, the results appear to justify the surgery, and these young patients will be followed with especial interest.

FIG. 10-A

FIG. 10-B

FIG. 10-C

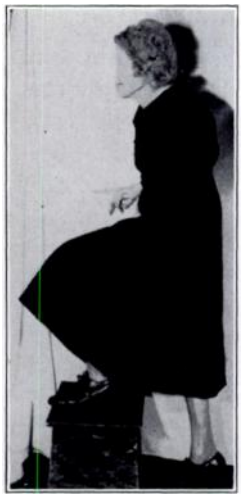

FIG. 10-D

Figs. 10-A through 10-D: This spry little lady, eighty-six years old, weighing about 100 pounds, was operated upon five years ago. A prosthesis was inserted following a high subcapital fracture of the neck of the femur. She has walked without support since two days after surgery. She climbs stairs, does her housework, walks rapidly with no limp and no pain. Overexercise produces some pain. She has full normal function of the hip and she says that she "cannot tell one hip from the other".

Fig. 10-A: Full abduction.

Fig. 10-B: Patient standing on right foot; left hip is in full flexion.

Fig. 10-C: Patient standing on left foot; right hip is in full flexion.

Fig. 10-D: Patient climbs stairs easily.

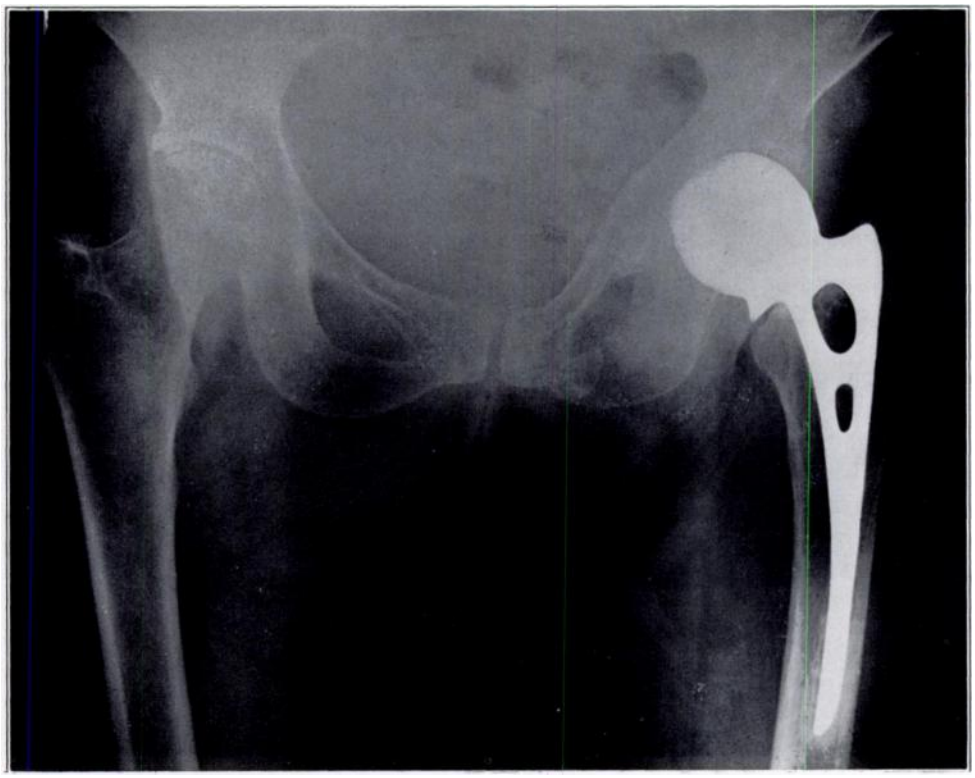

FIG. 10-E

Roentgenogram made five years after surgery shows the bone reaction to the prosthesis. There is increased density under the collar, along the calcar femorale, in the fenestrations, about the lower portion of the prosthesis, and under the tip of the stem. The loop of the prosthesis was removed to prevent its impingement against the rim of the acetabulum. The loop was lowered in later models. Full abduction of the thigh is now possible.

*Results*

Results were classified as *excellent* (little or no pain, no limp, 100 per cent motion, 90 to 100 per cent normal hip function); *good* (mild pain, slight limp, 100 per cent motion, 75 to 90 per cent normal hip function); *fair* (moderate pain, moderate limp, 60 to 75 per cent motion, 60 to 75 per cent normal hip function); *poor* (moderate pain, severe limp, 40 to 60 per cent motion, 40 to 60 per cent normal hip function); and *failure* (Table I).

TABLE V

PROSTHESIS SIZES

| | |
|---|---|
| 2⅛ inch head size | 6 |
| 2 inch head size | 12 |
| 1⅞ inch head size | 29 |
| 1¾ inch head size | 11 |
| 1⅝ inch head size | 3 |
| Total | 61 |

*Diagnosis*

There were sixteen different diagnoses. In the large majority, these were acute fractures, fractures with non-union, and osteo-arthritis with or without aseptic necrosis (Table IV).

*Head Sizes of Sixty-One Prostheses Used in Fifty-Five Patients*

Approximately 80 per cent of the prostheses used were large sizes — one and seven-eighths inches, two inches, and two and one-eighth inches. There were half as many prostheses sized two and one-eighth inches as two inches. Approximately 50 per cent of the fifty-five patients required the one-and-seven-eighths-inches prosthesis. This is interesting, since the prostheses which were used were considerably larger than those which are frequently recommended and are available (Table V).

*Limp and Support*

Patients who have been fitted with hip prostheses are advised to restrict their diets and to "take it easy" for the rest of their lives. They are advised to avoid excessive stress in the same way that one who uses a dental prosthesis avoids excessive chewing of hard or tough food which will cause soreness or pain. It has been demonstrated that excessive exercise or weight-bearing will cause soreness or pain about a hip prosthesis, which rest will relieve. All patients are advised to use a cane the balance of their lives, and frequently a Canadian crutch is recommended.

Since no important muscle attachment is divided in this operation, most patients have only a slight limp. A few patients have no limp and have practically normal function. This exceptional result should not be looked for, however, since no artificial appliance can be expected to function in the same manner as the normal hip.

## SUMMARY AND CONCLUSION

Great judgment should be exercised in the selection of patients for replacement of the femoral head and a careful postoperative program should be planned. The importance of partial weight-bearing for a period of at least six months should be emphasized, with a gradual increase as roentgenograms show the reaction of bone about the prosthesis. New-bone formation takes place within the fenestrations of the prosthesis. Once this has occurred, the stem cannot be removed without chiseling away the new bone. The prosthesis becomes, literally, self-locking. It is very interesting to see, roentgenographically,

the increasing density of bone in and under the prosthesis in the stress-bearing locations. If a prosthesis is to last indefinitely, it must be constructed in such a way that stress is distributed so as to produce a dynamic reaction, in accordance with Wolff's law. In this way, there gradually occurs a thickening of bone about the prosthesis enabling it to carry the normal load of weight and stress. The prosthesis becomes a part of the living bone.

Five years ago a preliminary report was made of our experience with a self-locking Vitallium prosthesis in thirty-three patients[2]. The present report reviews the same experience in 153 patients and in 159 operations during a period of six years.

There have been no fractures of the bone in applying the prosthesis, and no dislocations of the hip have occurred during the operation.

Apparently Vitallium is inert in the tissues, and it is possible that the prosthesis may last indefinitely.

Patients are made to understand that no artificial replacement can be expected to function as well as the normal hip and are urged to be careful. They are advised to always carry a cane or to use a light support.

An attempt is being made to follow all patients. Time has already shown conclusively that transplanted cancellous bone in the medullary canal undergoes metaplastic changes and that the bone becomes progressively denser in the areas of stress. Time has also shown, as was anticipated, that there is hyperplasia of bone in, under, and about the prosthesis when weight-bearing is properly applied.

Excessive weight-bearing stress or too short a stem results in pressure necrosis with a loose, clicking prosthesis and pain. With the stimulating stress of gradual weight-bearing, areas of increased density of bone appear about the prosthesis consistent with known mechanical and engineering principles.

When patients have been properly selected and when operation has been correctly performed, and postoperative follow-up care has been conscientiously carried out, this prosthesis appears to become a part of the femur and to carry the normal stress load of weight-bearing with minimal degenerative changes and with minimal pain.

The results so far are encouraging, and the increasing number of patients bears witness to growing confidence in the procedure.

Final results can be known and a thorough evaluation of the method can be made only after many years of experience.

NOTE: For their help, I wish to express my sincere appreciation to my associate Dr. G. A. Barnaby, to Mrs. Robert C. Fennell, Jr., and J. Maxwell Chappell, our office assistants, to Dr. V. L. Krueger, Staff Physician of the Columbia State Hospital, Mr. Jack Boineau, medical student and artist, and Mr. C. L. Wise, Chief X-ray Technician and photographer.

## REFERENCES

1. MOORE, A. T.: Metal Hip Joint. A Case Report. J. Bone and Joint Surg., **15**: 688–692, July 1943.
2. MOORE, A. T.: Metal Hip Joint. A New Self-Locking Vitallium Prosthesis. Southern Med. J., **45**: 1015–1019, 1952.
3. MOORE, A. T.: Hip Joint Fracture (A Mechanical Problem). *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1953. Vol. 10, pp. 35–49. Ann Arbor, J. W. Edwards, 1953.