Continuing Education
Independent Study Series

EXACTECH TOTAL HIP ARTHROPLASTY

Association of Surgical Technologists

ASSOCIATION
OF SURGICAL
TECHNOLOGISTS

AEGER PRIMO –
THE PATIENT FIRST®

Association of Surgical Technologists, Inc.
7108-C S. Alton Way, Suite 100
Englewood, CO 80112-2106
303-694-9130

Materials reprinted by permission of Exactech, Inc. Examination copyright© 1996 by the Association of Surgical Technologists, Inc. All rights reserved. Printed in the United States of America.

PREFACE

"Exactech Total Hip Arthroplasty" is part of the AST Continuing Education Independent Study Series. The series has been specifically designed for surgical technologists to provide independent study opportunities that are relevant to the field and to support the educational goals of the profession and the Association.

Acknowledgments

AST gratefully acknowledges Exactech, Inc., Gainesville, Florida, for giving its permission for the reproduction of these materials.

INTRODUCTION

Purpose

The purpose of this module is to give the learner an understanding of total hip arthroplasty using the Exactech Hip System. Upon completing this module, the learner will receive 2 continuing education (CE) credits in category 3.

Objectives

Upon completing this module, the learner will be able to do the following:

1. Describe the surgical procedure and the instrumentation needed for a cemented total hip arthroplasty.
2. Describe the surgical procedure and the instrumentation needed for a noncemented total hip arthroplasty.
3. Discuss the differences between the cemented and noncemented total hip implants.

Using the Module

1. Read the information provided, referring to the appropriate figures.
2. Complete the enclosed exam without referring back to the text. The questions are in a multiple choice format. Select the best answer from the alternatives given.
3. Mail the completed exam to AST, CEIS Series, 7108-C S. Alton Way, Suite 100, Englewood, CO 80112-2106. Please keep a copy of your answers before mailing the exam. You must return the original copy of the answer sheet; this exam may not be copied and distributed to others.
4. Your exam will be graded, and you will be awarded continuing education credit upon achieving a minimum passing score of 70%. If you are an AST member, your credits will be automatically recorded and you do not need to submit the credits with your yearly CE report form.
5. You will be sent the correct answers to the exam. Compare your answers with the correct answers to evaluate your level of knowledge and to determine what areas you need to review.

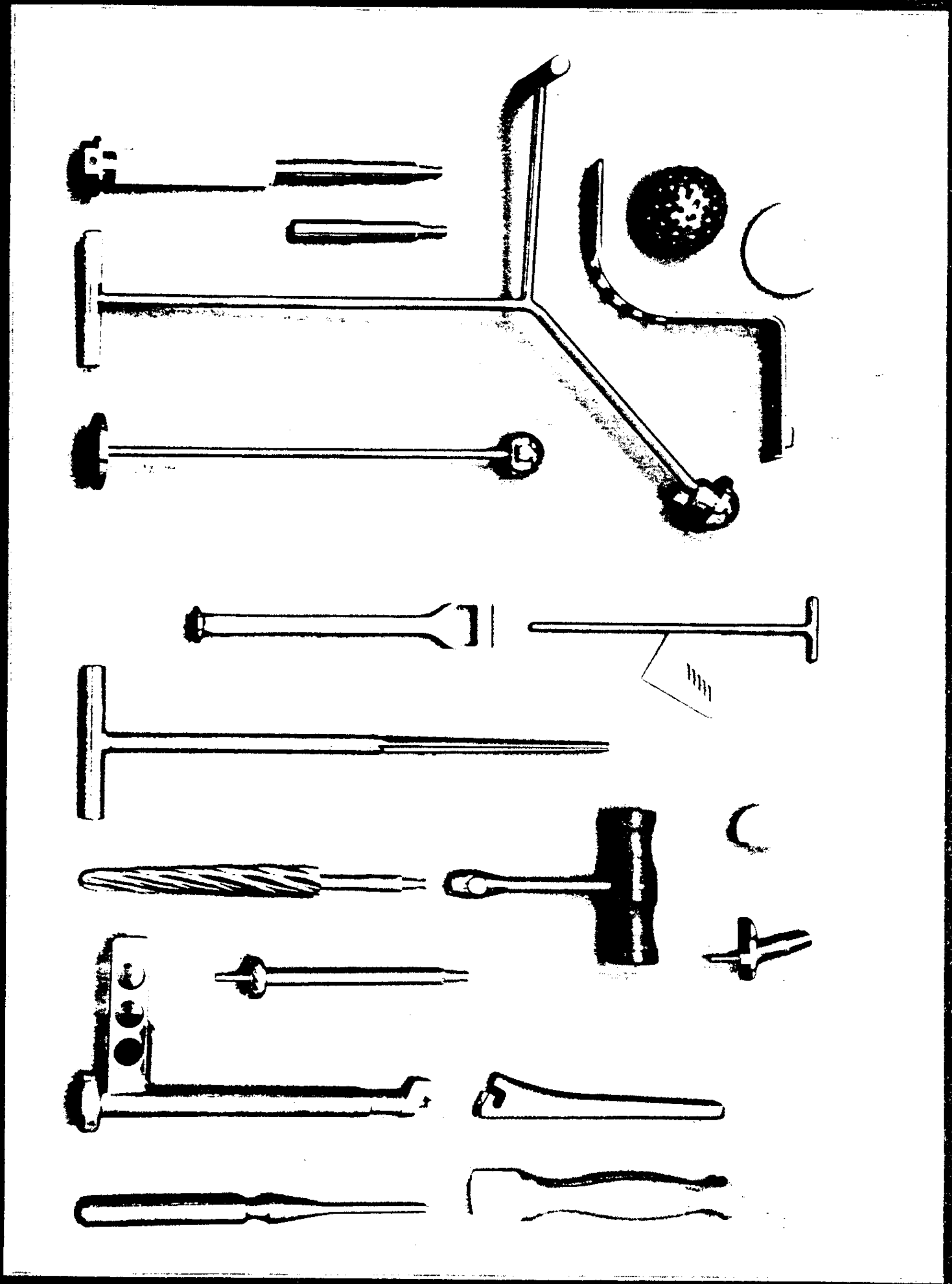
Studying Technical Material

To study technical material, find a quiet place where you can work uninterrupted. Sitting at a desk or work table will be most conducive to studying.

Having a medical dictionary available as you study is very helpful so you can look up any words with which you are unfamiliar. Make notes in the margins of any new definitions so that you can review them.

The ultimate test of how well you learn this material is your ability to relate your knowledge to what is happening in the surgical field. Apply your knowledge to what you observe during surgery.

Operative Technique



Exactech®
INC.

Cemented Total Hip Arthroplasty

Exactech®
INC.

Cemented Total Hip System

Surgical Technique

in consultation with

William Petty, M.D.
Professor and Chairman
Department of Orthopaedics
University of Florida College of Medicine
Gainesville, Florida

Gary J. Miller, Ph.D.
Associate Professor
Department of Orthopaedics
University of Florida College of Medicine
Gainesville, Florida

© 1988, 1989 Exactech, Inc.

Exactech®

CEMENTED TOTAL HIP SYSTEM

Total hip arthroplasty is one of the most successful surgical procedures ever devised, not only in orthopaedic surgery but in all of medicine. The results of total hip arthroplasty have allowed many individuals who faced permanent disability from arthrosis of the hip to resume full and productive lives.

Orthopaedic surgeons and their patients have come to expect good to excellent results from cemented total hip arthroplasty in 90 to 95 percent of the procedures.[5,9] However, studies of long-term results of total hip arthroplasty reveal a decrease with time in the percentage of good and excellent results.

A careful review of these series, along with extensive *in vitro* and finite element analysis studies of design and technique, reveal that certain designs and techniques result in unacceptably high long-term failure rates. Major complications include neurovascular damage, thromboembolic disease, infection, and mechanical loosening or breakage.

Appropriate prosthesis design combined with meticulous surgical technique can deter these long-term shortcomings, and precipitate excellence in both short-term and long-term results in cemented total hip arthroplasty.[7]

A cemented total hip arthroplasty of optimal design and technique appears to be the preferred treatment for the vast majority of patients over age 60 with severe hip arthrosis.[7] The Exactech Cemented Total Hip System has been designed and manufactured without compromise to produce a state-of-the-art cemented total hip prosthesis system which, when combined with careful surgical technique, provides optimal treatment for patients requiring cemented hip arthroplasty.

A major premise in the design of the Exactech Cemented Total Hip System is that an attempt to design a single prosthesis for cemented and for press fit use compromises the design of the prosthesis because the design criteria for cemented and non-cemented prostheses are different. The Exactech Cemented Total Hip System has been created with optimal design for cemented total hip arthroplasty. The System consists of an array of sizes of both the acetabular component and femoral stem, variable neck length femoral heads attached to the femoral stem by a taper fitting, and a stem centralizer (Fig. 1).

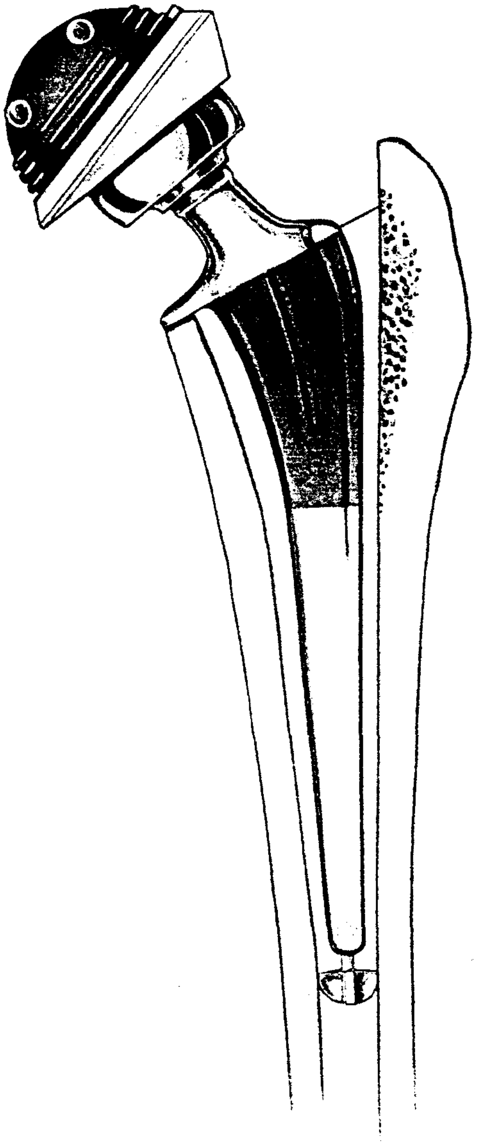


Figure 1: Exactech Cemented Total Hip Prosthesis

TABLE

STEM SIZE AND NECK LENGTH

Stem Size	1	2	3	4	5
Stem Length (mm)	120	130	140	150	160
Short Neck (− 5)	25	30	30	35	35
Standard Neck (0)	30	35	35	40	40
Long Neck (+ 5)	35	40	40	45	45
Extra Long Neck (+ 10)	40	45	45	50	50

Femoral Stem

The Exactech Femoral Stem is available in five sizes that have been designed based on anthropometric studies of the proximal human femur. Stem lengths vary from 120 to 160 millimeters in 10mm gradations (Table). Because larger individuals have greater stresses across their prosthesis femur composite, the increased length in the larger stems decreases bone cement stress for these patients.[3]

When the stem is implanted utilizing the Exactech Total Hip Instrument System, the surgeon can obtain placement of a stem of maximum cross section, resulting in decreased cement stresses while maintaining the appropriate mantle of cement surrounding the stem.[3,4]

The stem incorporates a broad medial collar which allows decreased proximal cement stress and improved stress transfer through the medial cortex of the femoral neck.[10] The femoral neck is elliptical in shape which allows improved range of motion and reduces the possibility of dislocation while maintaining excellent strength characteristics. The tapered neck is designed and manufactured for precise fitting with the internal taper of the variable neck length femoral head components (Table).

Stem Centralizer

The neutral position is best for femoral stem placement in cemented total hip arthroplasty and the prosthesis cement bone composite is optimal with an even mantle of cement.[6,13] The Exactech Stem Centralizer made of preformed polymethylmethacrylate allows the surgeon to center the stem consistently and place it in neutral position. The preformed polymethylmethacrylate centralizer bonds to the cement placed in the femoral canal (Fig. 1).

Femoral Head

The Exactech Femoral Head is available in four neck lengths; short (-5), standard (0), long (+5), extra long (+10), and in two diameters; 26mm and 32mm. The femoral head mates with the femoral stem by its precise internal taper (Fig. 2). A unique head and taper design produces a shorter taper sleeve in the longer neck lengths. This design reduces the possibility of dislocation caused by sleeve impingement.

Acetabular Component

The acetabular component consists of a cobalt chromium alloy metal shell bonded to a high molecular weight polyethylene insert with integral polymethylmethacrylate spacers (Fig. 1). The metal shell incorporates smooth cement ridges and a nonporous microtextured surface for enhanced cement fixation.

The integral polymethylmethacrylate spacers provide an even 3mm mantle of cement surrounding the acetabular component.[11] The high molecular weight polyethylene insert has a 10 degree extended superior roof which allows improved stability while permitting the metal shell to be contained completely within the bony acetabulum. *In vitro* studies reveal this acetabular component design to result in near normal strain patterns in the pelvis after acetabular reconstruction.[8]

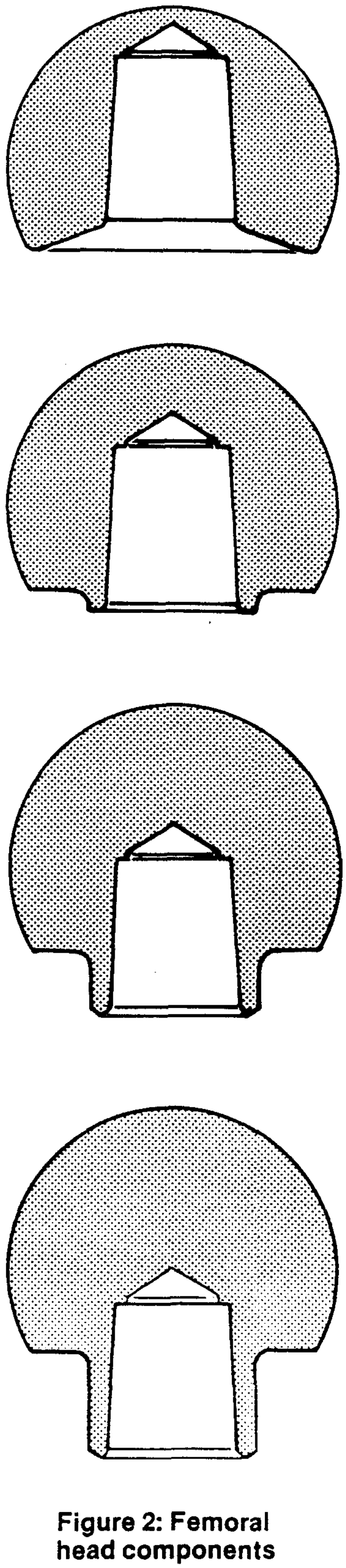


Figure 2: Femoral head components

Acetabular Instruments and Trials

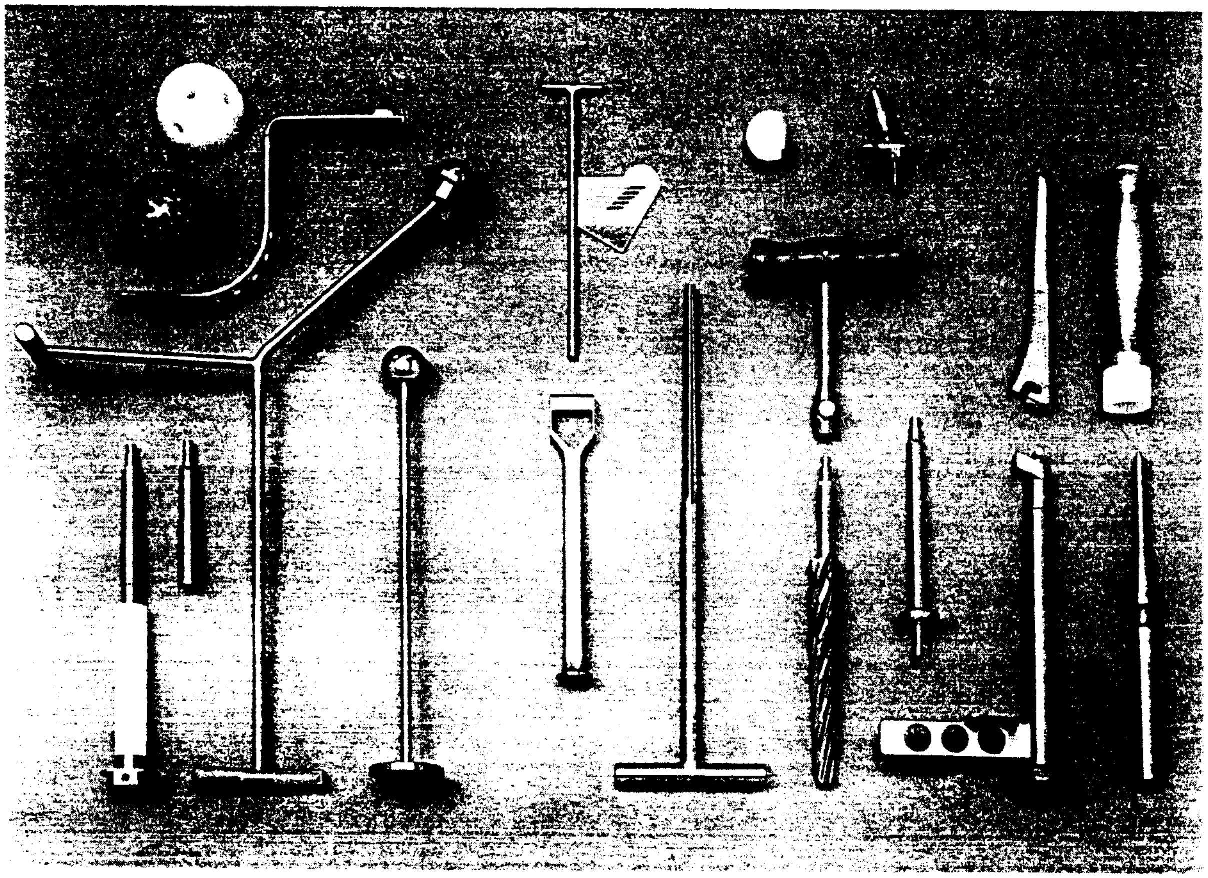
Acetabular reamer heads are sized in two millimeter increments from 42 to 60 millimeters to provide exact correspondence with the acetabular component cement mantle composite (see cover and photo below).

The acetabular trials have the exact shape of the acetabular component and its cement mantle, and allow for visualization of the prepared acetabular bed. The acetabular cup positioner provides the surgeon with the control for placing the acetabular component in optimal position. The cup pusher allows the surgeon to maintain compression of the prosthetic component against the bone cement without movement during cement polymerization.

Femoral Instruments and Trials

The Femoral Instrument System consists of the femoral neck osteotomy guide, intramedullary flexible femoral reamers, a single rigid intramedullary reamer, five size-specific femoral broaches, femoral neck planers, a stem impactor, and a femoral head impactor (see cover and photo below). Size-specific collar neck trials and femoral head trials are used for trial reduction.

The Femoral Instrument and Trial System allows preparation of the femur to accept both the femoral stem and bone cement, and facilitates consistent collar contact with the medial femoral neck cortex.



Preoperative Planning

Exactech templates with 20 percent magnification are available for both the femoral and acetabular components. It may be helpful to template the contralateral hip as a guide if it is normal, but templating will be less likely to correspond to intraoperative findings where the final decision about prosthesis size selection is made, if final templating is not performed for the hip requiring arthroplasty.

The acetabular template should be placed in the position of the normal acetabulum to allow for maintenance of subchondral bone and a 3mm cement mantle.

The dotted line on the template outlines the cement mantle and thus the final sphere of reaming. With the acetabular template held in the desired position, a mark is made at the center of rotation of the acetabular component through the small hole in the template.

An estimate is made of the appropriate size femoral stem and that template is placed over the proximal femur. The solid line around the femoral stem is placed to fill the proximal femur to the cortex since this represents the broach and thus the outside of the cement mantle.

The surgeon selects the desired neck length; normally, templating should be done for the standard (0) neck length. The center of rotation of the femoral head, which is marked with a crosshatch, is placed over the mark made during acetabular templating. Medial or lateral adjustments can be made along the lines extended from the crosshatch in order to place the femoral stem appropriately over the femoral canal.

When this position has been established, a mark is made through the small holes medially and laterally along the femoral neck. A straight edge is used to connect the two dots, describing the line of femoral neck osteotomy.

The distance from the superior portion of the lesser trochanter to the osteotomy line may be used intraoperatively as a guide for the level of osteotomy. During femoral templating, the surgeon should note the variance, if any, of the horizontal line extended from the center of rotation of the femoral head above or below the tip of the greater trochanter. This will be helpful during intraoperative assessment of extremity length.

THE PROCEDURE

This description will include the lateral decubitus position for total hip replacement, though the flexibility of the Exactech Cemented Total Hip System allows for performance of the procedure in the supine position if the surgeon prefers. When the lateral position is used, it is important to have the patient well stabilized in position.

Surgical Approach

The Exactech Cemented Total Hip System allows for performance of total hip arthroplasty through any standard approach for total hip replacement based on the surgeon's experience and preference. The posterior approach will be described in the operative technique.

The skin incision is centered over the greater trochanter extended distally along the proximal femur and extended proximally, curving it gently posteriorly (Fig. 3). The fascia lata is incised directly laterally over the greater trochanter and proximal femur and curved slightly posteriorly proximally; when the fibers of the gluteus maximus muscle are encountered, they may be bluntly separated.

The portion of the bursa and the adipose tissue over the short external rotators are excised or reflected posteriorly to expose the short external rotator muscles. The short external rotators are incised along their attachment to the greater trochanter and gently stripped away from the capsule with a periosteal elevator (Fig. 4). The surgeon may wish to tag the piriformis tendon with a suture to allow for repair during closure.

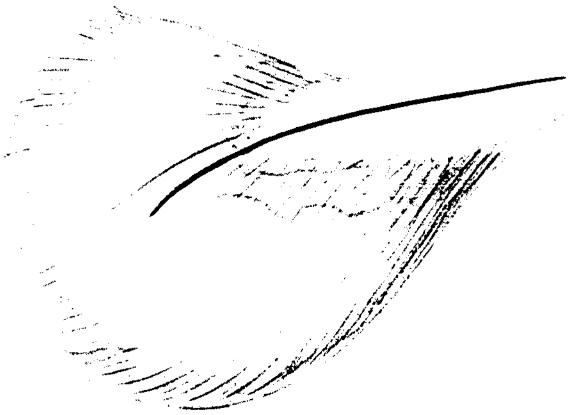


Figure 3: Skin incision

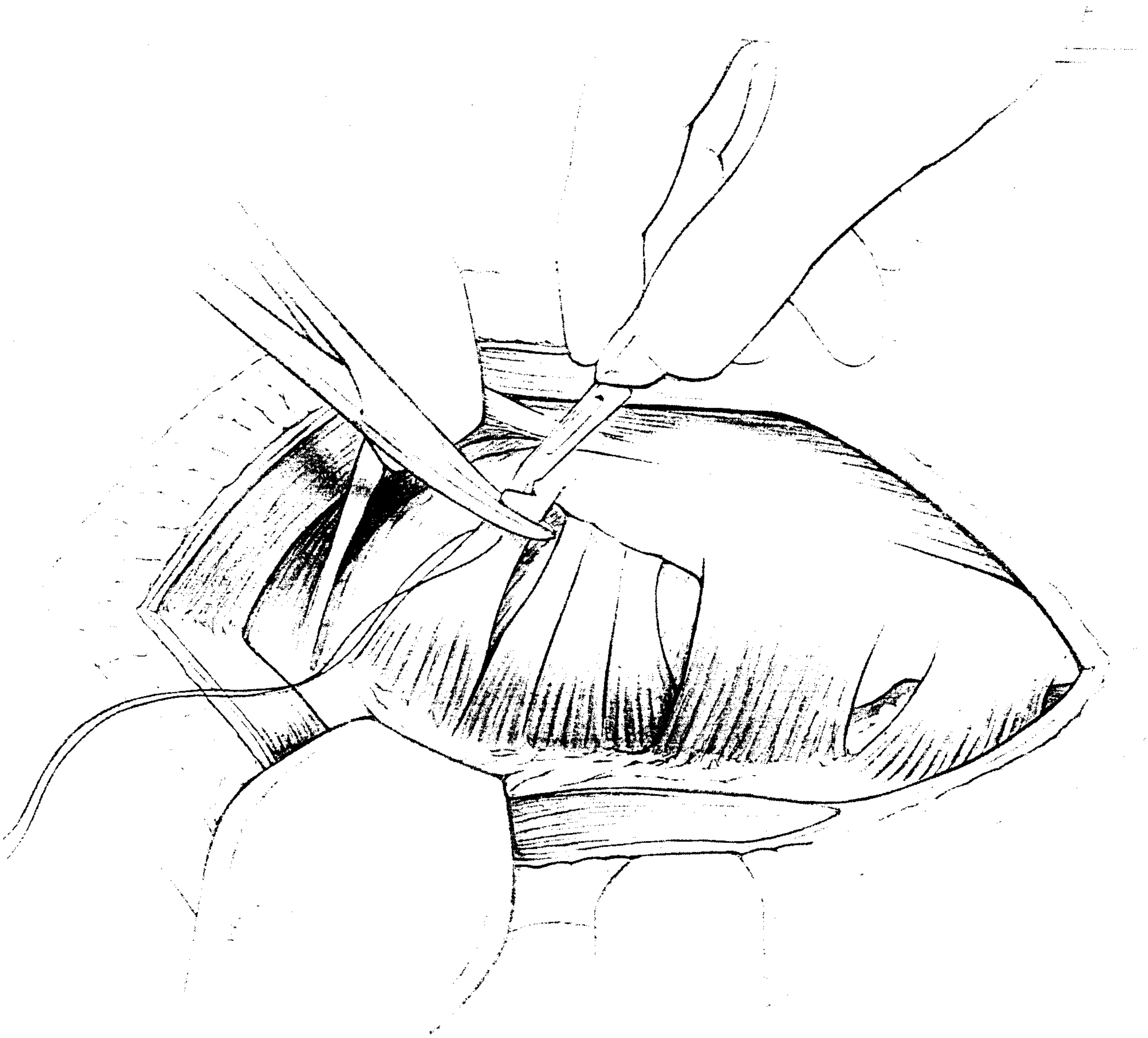


Figure 4: Incision of the external rotators

Capsulotomy

A small, blunt retractor may be placed medial to the posterior border of the gluteus medius muscle to expose the posterior border of the gluteus minimus (Fig. 5). The interval should be established between the gluteus minimus muscle and superior capsule with a periosteal elevator. The elevator is used to expose the inferior capsule to approximately "six o'clock." It is helpful to place a cobra-type or similar retractor between the gluteus minimus and superior capsule as well as around the inferior capsule and to retract the short external rotators with a smooth, blunt retractor.

Capsulotomy is performed across the superior capsule and extended posteriorly around to the inferior capsule. Both visualization and dislocation may be improved if a portion of the posterior capsule is excised.

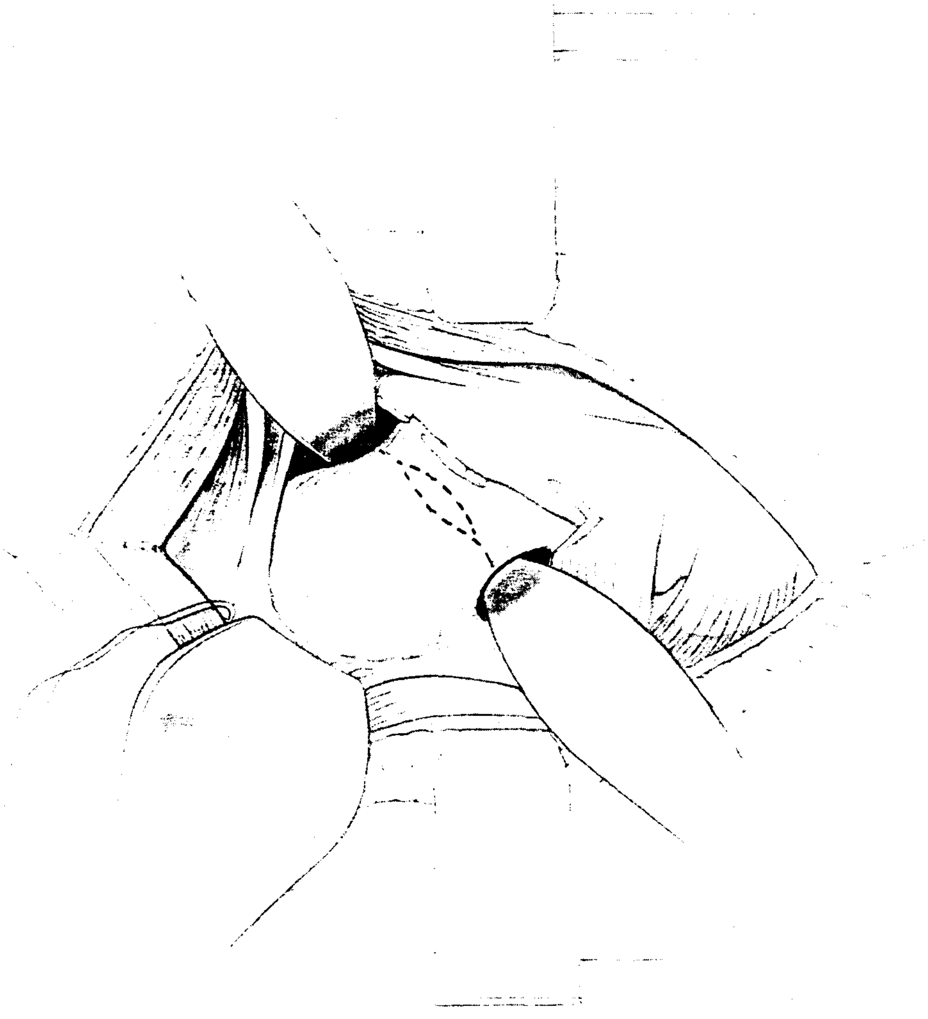


Figure 5: Capsulotomy

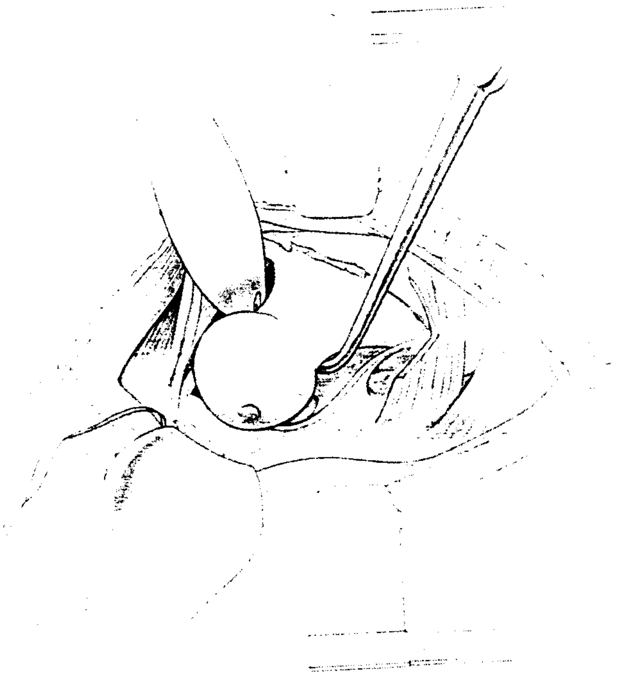


Figure 6: Dislocation

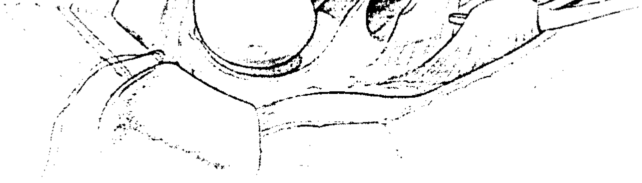


Figure 7: Optional release of the gluteus maximus tendon

Dislocation

A large bone hook is placed around the femoral neck and with gentle internal rotation of the extremity and traction on the bone hook, the femoral head is dislocated posteriorly (Fig. 6). Soft tissues are cleared along the intertrochanteric line to the proximal border of the lesser trochanter to improve exposure for selection of the neck osteotomy site. At times, exposure may be enhanced by release of the gluteus maximus tendon attachment to the femur (Fig. 7).

The Femoral Neck Osteotomy Guide is aligned with the femur by either palpating the femur through the muscles or directing the guide toward the center of the popliteal fossa (Fig. 8). The slot representing the selected neck length is centered over the center of rotation of the femoral head (Fig. 9). The line extending from the slot over the center of the femoral head is correlated with the relationship of the tip of the greater trochanter to the center of rotation determined during preoperative templating. The appropriate neck resection

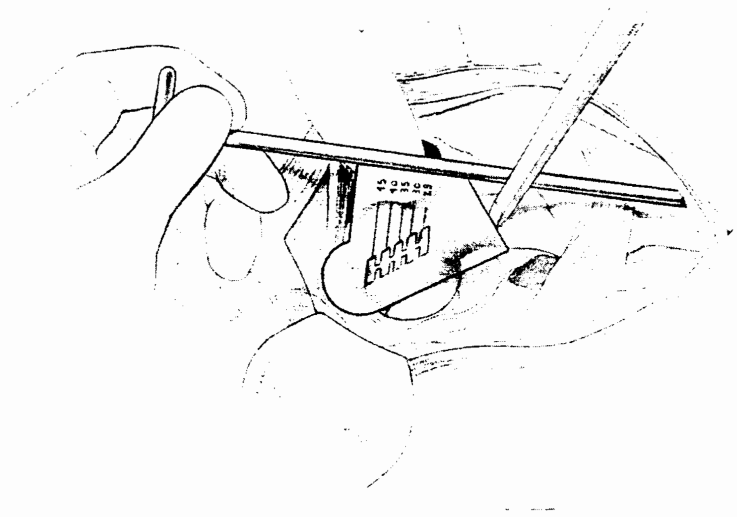


Figure 8: Neck osteotomy guide placement

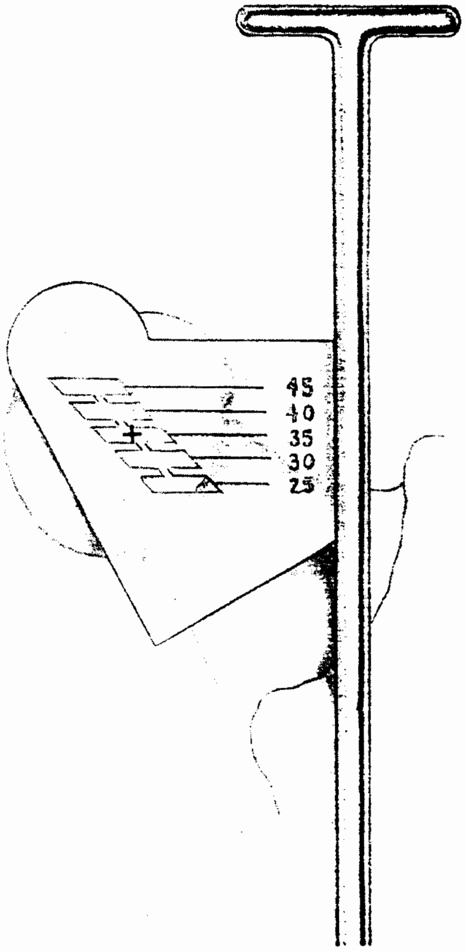


Figure 9: Alignment of neck osteotomy guide

level also can be determined by measuring the distance determined preoperatively between the superior edge of the lesser trochanter and the junction of the medial femoral neck and osteotomy surface of the neck osteotomy guide. The neck resection level is marked. An oscillating saw is used to perform the osteotomy (Fig. 10). It usually will be necessary to cut the superior portion of the femoral neck along the medial border of the greater trochanter to avoid cutting into the greater trochanter.

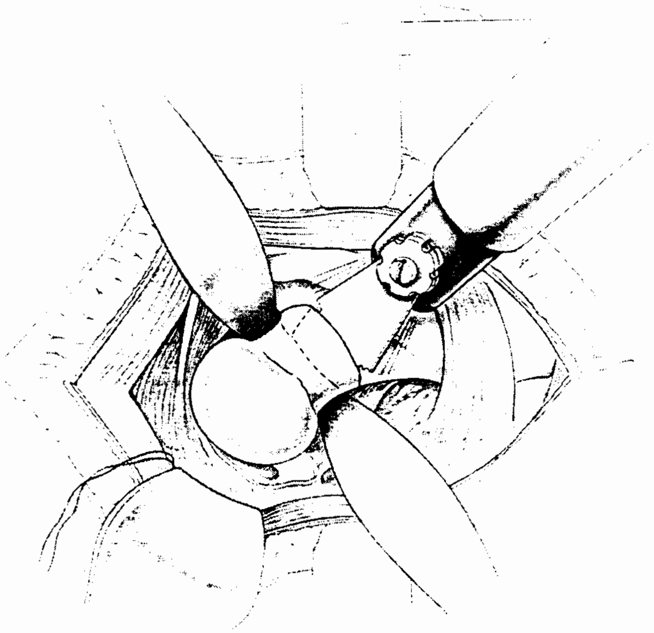


Figure 10: Femoral neck osteotomy

Acetabular Preparation

The bone hook may be placed in the proximal femur to place tension on the remaining anterior capsule. A blunt clamp is then passed just anterior to the capsule and anterior capsulotomy performed (Fig. 11). Some surgeons prefer to expose the hip anteriorly and incise the anterior capsule prior to dislocation.

The superior acetabular retractor is placed utilizing drill bits; blunt cobra retractors are placed anteriorly and inferiorly to the acetabulum. If necessary, a smooth, blunt retractor should be used posteriorly (Fig. 12).

Capsule around the edge of the acetabulum, labrum, and osteophytes are removed. Soft tissue, including any remaining articular cartilage or fibrocartilage is removed from the acetabulum. Normally, the acetabular reamer head selected for initial reaming is two or three sizes (4 or 6mm) smaller than the size templated. The surgeon may wish to direct initial reaming more medially with the first reamer, but subsequent reaming should be done in 30 to 35 degrees of abduction and 20 degrees of forward flexion (Fig. 13).

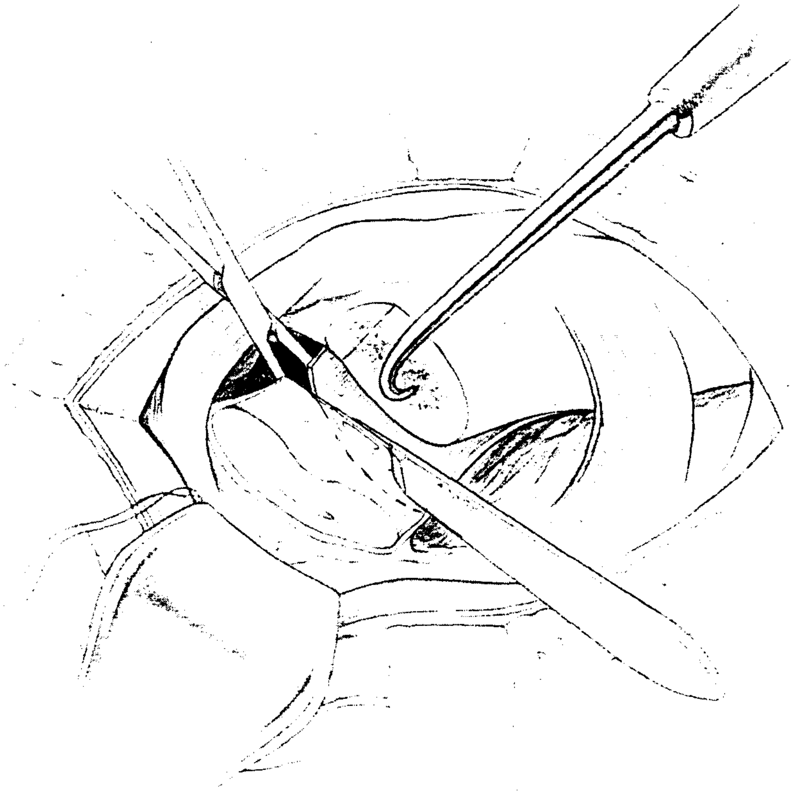


Figure 11: Incision of the anterior capsule

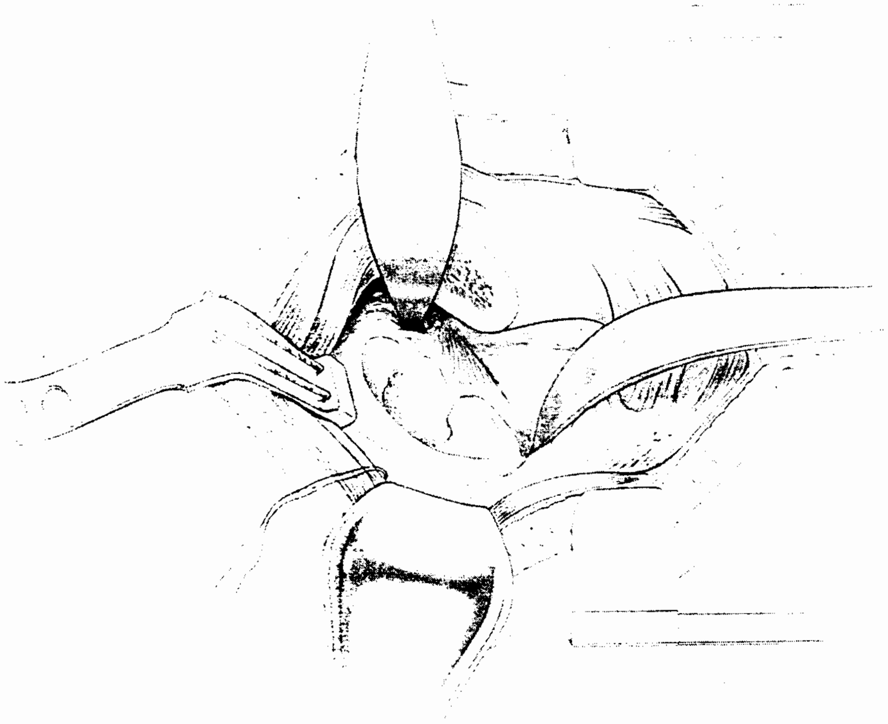


Figure 12: Placement of acetabular retractors

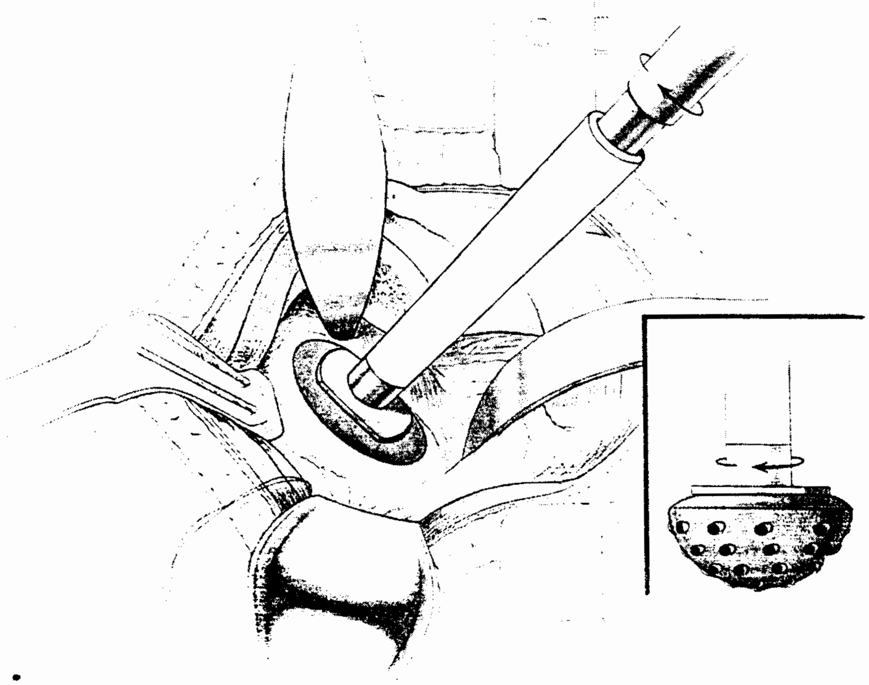


Figure 13: Acetabular reaming

When reaming is complete, the appropriate size acetabular trial is placed on the positioner and the position of 30 to 35 degrees abduction and 20 degrees forward flexion established (Fig. 14a). The positioner may be removed and the quality of fit visualized through the visualization holes. The acetabular trial is equivalent to the last size reamer head used. It is sized to include the acetabular component and 3mm cement spacers (Fig. 15).

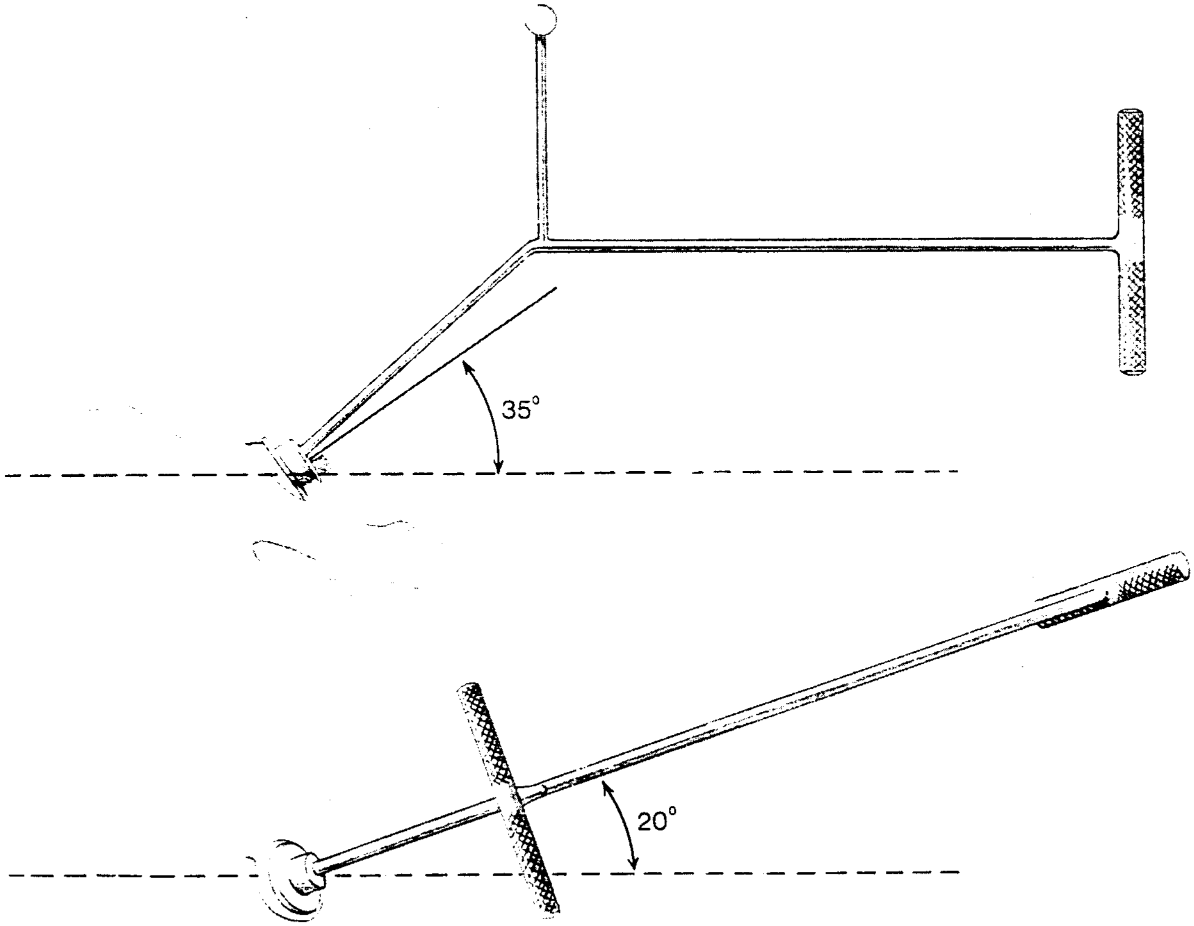


Figure 14a: Acetabular prosthesis positioning

After the appropriate acetabular size has been determined and evaluated, the trial component is removed and the acetabulum is further prepared by placing additional anchoring holes and cleansing the area with pulsed lavage if the surgeon desires (Fig. 16).

The surgeon mixes and prepares the cement and places it in the acetabulum by syringe or hand.

If desired, the surgeon may utilize a pressurization device to pressurize the cement. The Exactech Cemented Acetabular Component has been designed with a beveled lateral lip to provide cement pressurization during insertion (Fig. 15).

The acetabular component is attached to the positioner with its extended roof positioned superiorly. The acetabular positioner is designed to prevent incorrect attachment of the acetabular component (Fig. 14a).

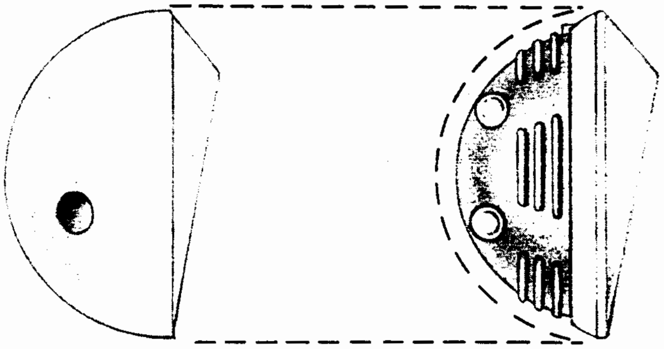


Figure 15: The acetabular trial is sized to include the cement mantle

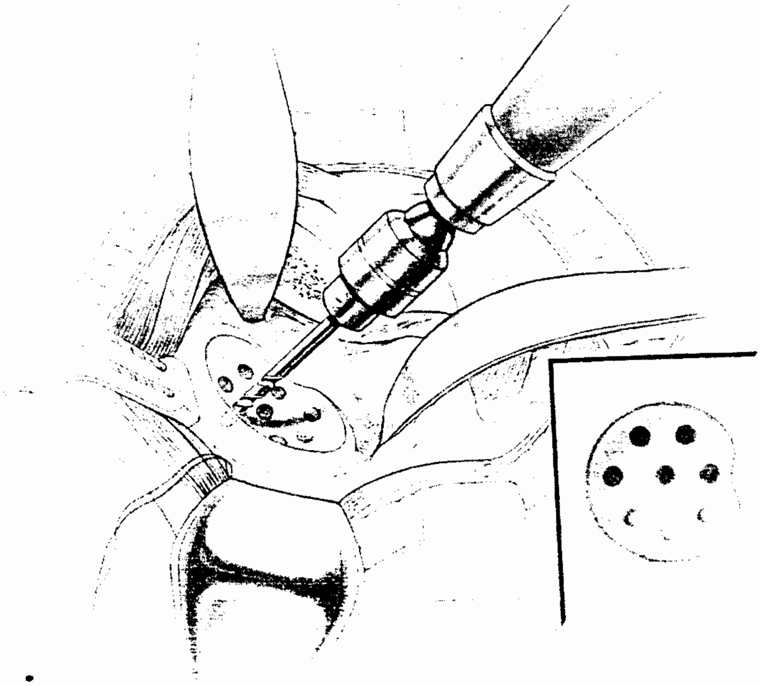


Figure 16: Final acetabular preparation

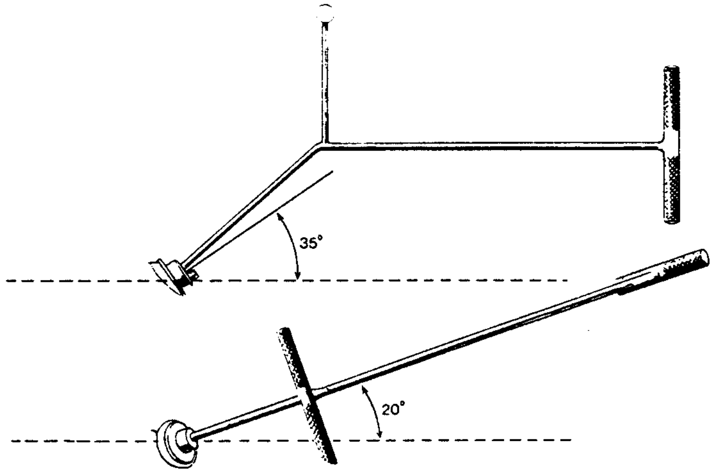


Figure 14b: Acetabular prosthesis positioning

Acetabular Component Positioning

Appropriate cup position varies depending on patient anatomy and patient position on the operating table (Fig. 14b). Normally, the face of the acetabular component should be placed in 30 to 35 degrees of abduction and 20 degrees of forward flexion. Many surgeons also take the position of the patient's bony acetabulum into consideration when placing the acetabular component. Holding the vertical bar of the acetabular component positioner in the vertical position will provide the 30 to 35 degree abduction of the acetabular component. The horizontal bar of the acetabular component positioner is utilized to achieve 20 degrees or the surgeon's selected amount of forward flexion.

The surgeon may elect to utilize the acetabular component positioner to hold the acetabular component until the cement has polymerized, but may prefer to remove the cup positioner after position has been established and hold the acetabular component with the acetabular pusher. This reduces the likelihood of movement of the acetabular component during polymerization and makes removal of excess cement easier.

Femoral Preparation

Refer to sizing established during intraoperative templating. Place a hip skid or similar retractor to elevate the proximal femur. The box osteotome is used to remove any remaining lateral portion of femoral neck and medial cortical portion of greater trochanter to allow straight entry into the femoral canal (Fig. 17).

Initial entry into the femoral canal is made with the T-handled tapered reamer (Fig. 18). It may help in establishing direction to palpate the proximal femur through the muscles during insertion of the tapered reamer.

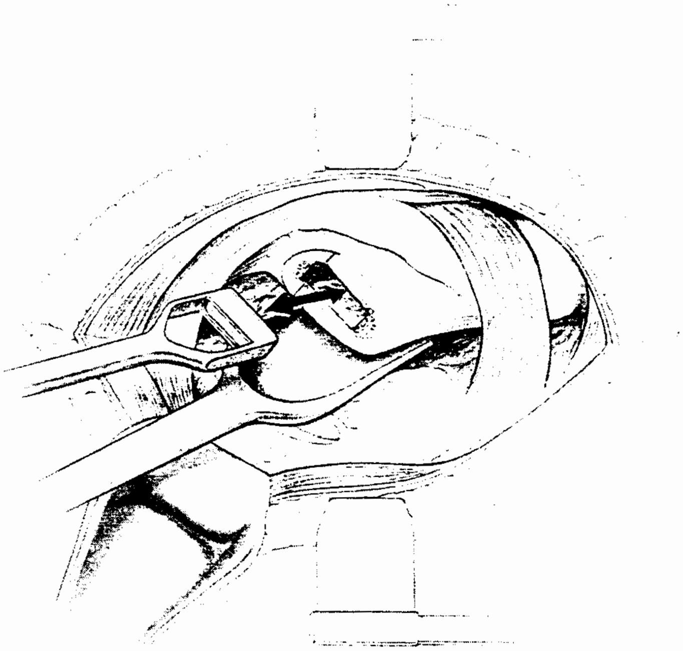


Figure 17: Lateralization of entry point into femoral canal

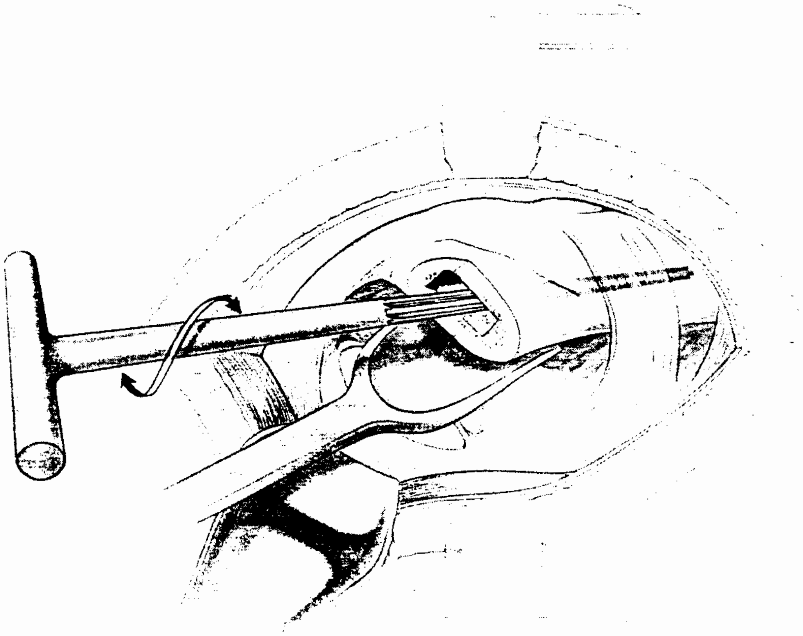


Figure 18: Entry into femoral canal with T-handled tapered reamer

Flexible Reaming

A guide wire is placed in the femoral canal and progressive sizes of flexible reamers in 1mm increments are used to prepare the distal portion of the femoral bed to 3 centimeters distal to the selected stem length and in diameter to the point of cortical "chatter" (Fig. 19). The maximum diameter flexible reamer used determines the size of stem centralizer.

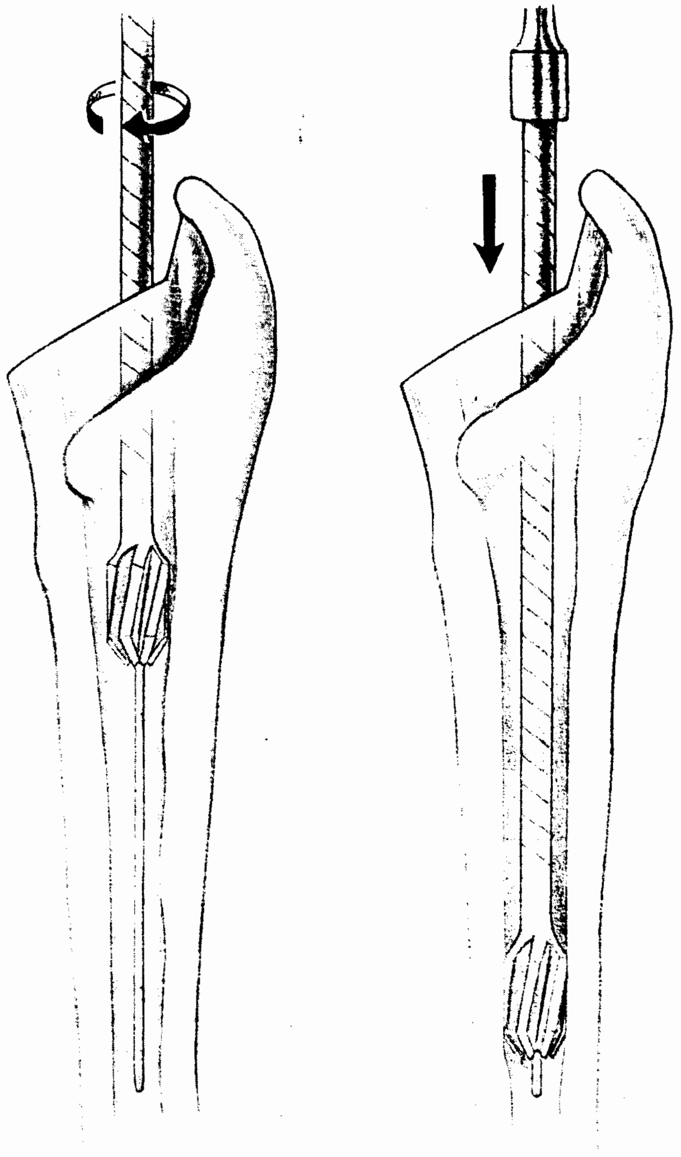


Figure 19: Flexible reaming

Mid-Stem Preparation

The rigid intramedullary reamer is used to prepare the bone at the mid-portion of the femoral stem and the trochanteric bone (Fig. 20). This reamer has blunted distal cutting surfaces to avoid distal cutting. A T-handle is supplied with the instrumentation system for use with the rigid reamer.

Reaming should be performed to the depth of firm resistance, but not forced beyond this point. At this point the blunted distal tip will cause the reamer to rotate easily without further penetration. The unique taper of the Exactech intramedullary reamer automatically provides proper preparation of the femur for any of the five sizes of the Exactech femoral stem. The reamer will not advance completely when preparing for the smaller sizes, while for a PS-05 it will advance all the way into the femur. The intramedullary reamer also further prepares the medial portion of the greater trochanter to allow for neutral placement of the femoral stem.

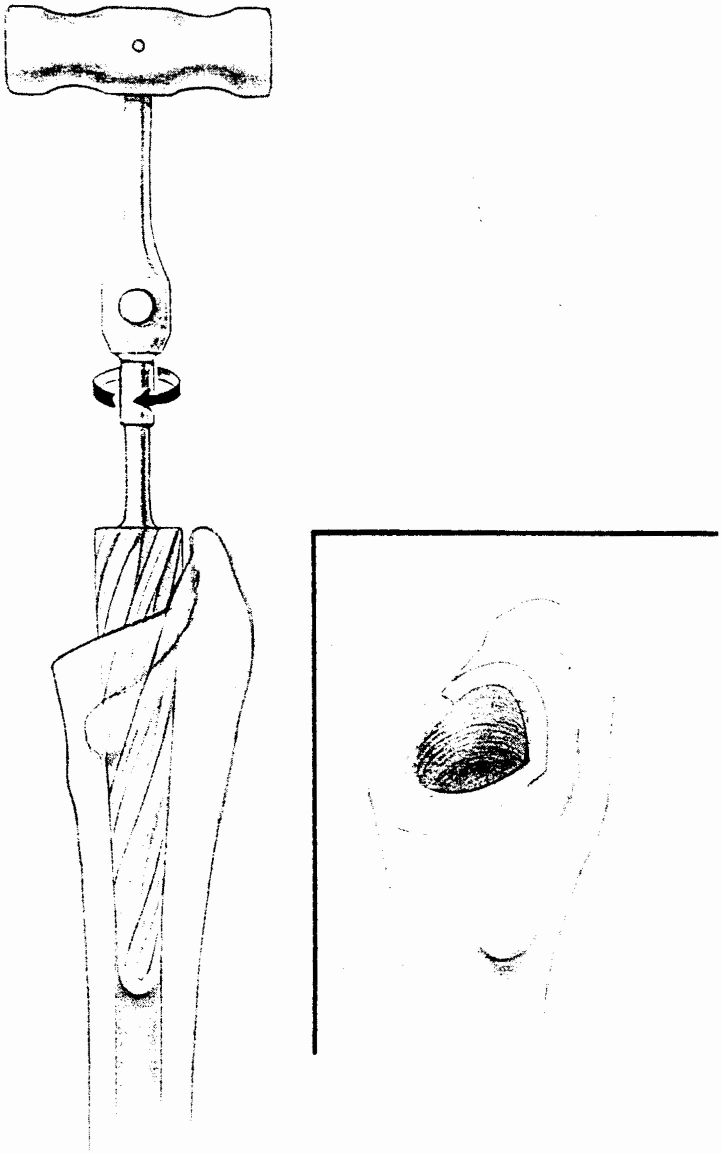


Figure 20: Mid-stem preparation

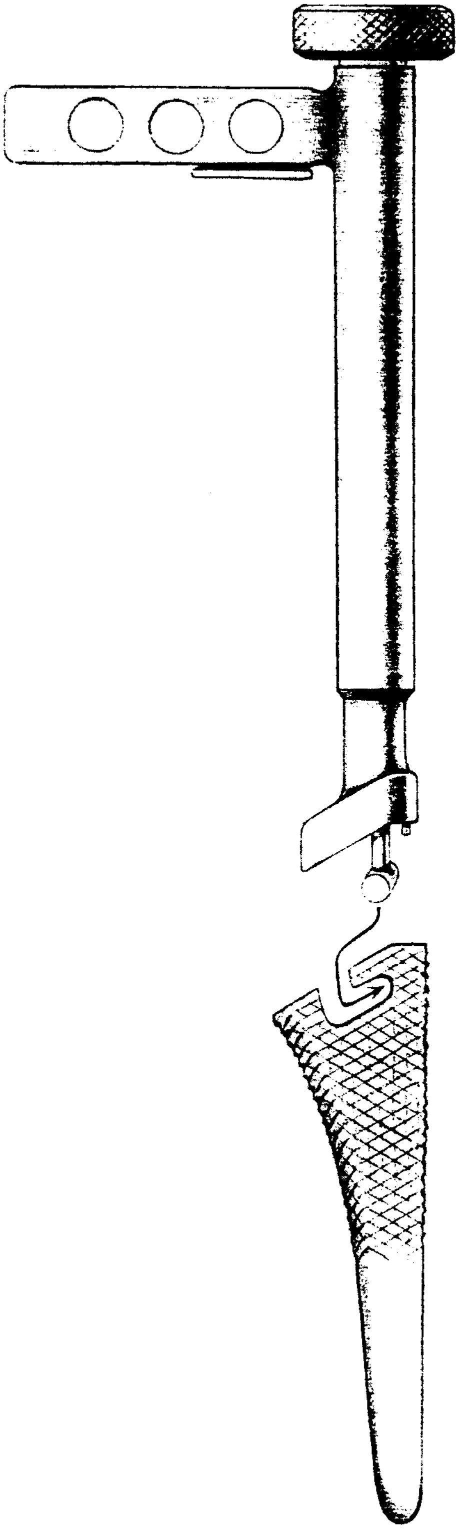


Figure 21: Femoral broach and handle

Proximal Femoral Preparation

Normally, it is best to begin with a broach two sizes smaller than the size stem selected during preoperative templating. The broach handle is placed on the broach and the broach handle knob tightened (Fig. 21). The broach handle provides for rapid attachment to the broach with rigid fixation and provides striking surfaces for both insertion and removal of the broach.

As the surgeon drives the broach into the femur, the broach may rotate slightly into anteversion (Fig. 22). The broach that is two sizes smaller than the templated stem size normally passes into the femur easily. If substantial resistance is met in inserting the broach selected preoperatively, the surgeon should not risk cortical fracture, but should select the next size smaller femoral stem. If this is the case, it may be necessary to adjust the femoral neck length.

For example, if preoperative templating suggests that a #2 femoral stem is appropriate and at the time of surgery the surgeon selects a #1 femoral stem, the femoral neck of the #1 stem is 5mm shorter than that of the #2 stem. Therefore, if the standard (0) femoral neck length was selected during preoperative templating, changing from the #2 to the #1 stem will require using the long (+5) neck femoral head to achieve the appropriate length.

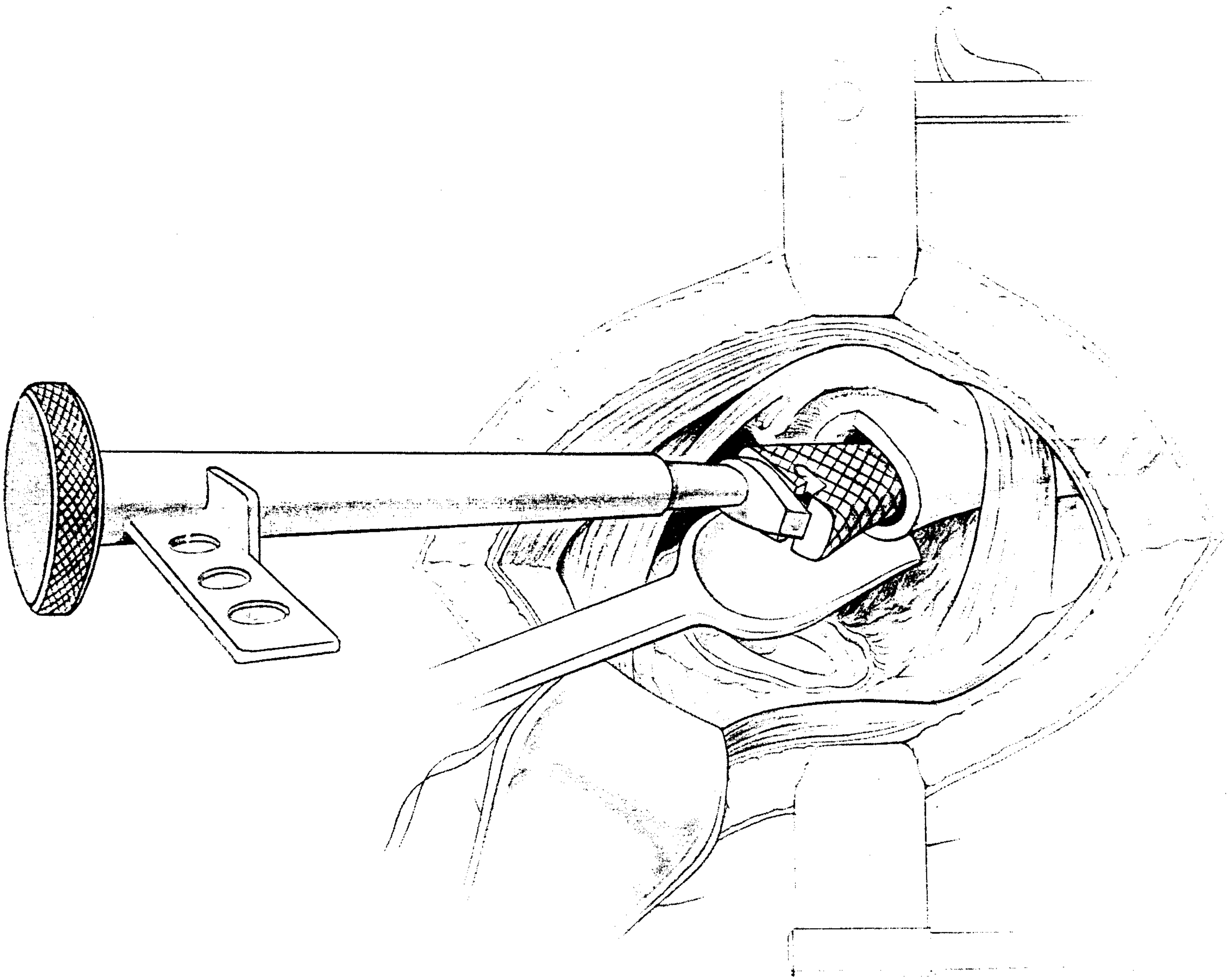


Figure 22: Insertion of femoral broach

Trial Reduction

When the appropriate size broach is in place, either the oscillating saw or the femoral neck planer may be used to make the final adjustments for optimal fit of the collar against the medial femoral neck cortex (Fig. 23). The femoral neck trial and femoral head trial should be placed and the hip reduced (Fig. 24).

Limb length can be assessed by evaluating the relationship of the level of the tip of the greater trochanter to the center of rotation of the femoral head. If preferred, the surgeon may use other methods of assuring appropriate length. The hip should be placed through a range of motion to assure that stability has been achieved. The hip is then dislocated. Trial components are removed.

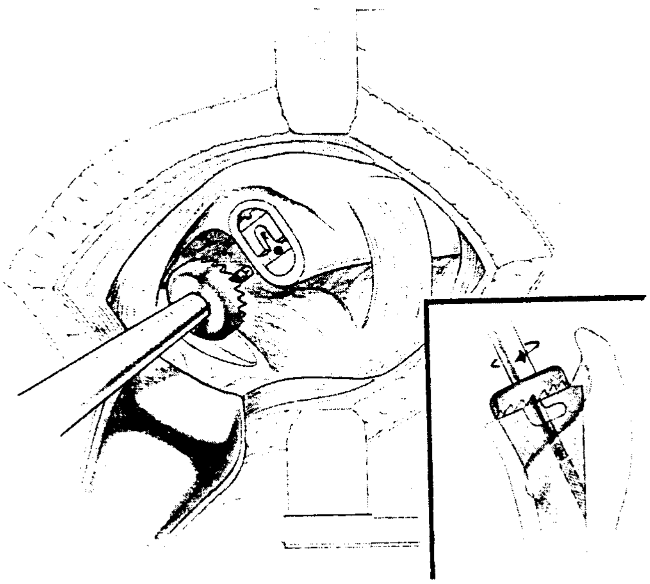


Figure 23: Preparation of the medial femoral neck cortex

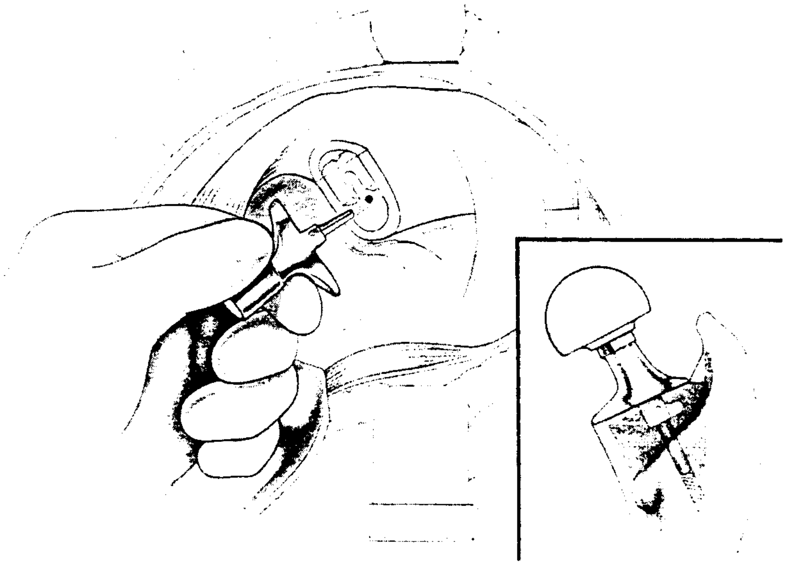


Figure 24: Placement of the collar neck trial and trial head

Final Femoral Preparation

The surgeon should use his/her method of choice for final preparation. This preparation may include brushing of the intramedullary canal and cleansing with pulsed lavage. A cement restrictor is placed 1.5 to 2 centimeters distal to the tip of the femoral stem.

Cement is mixed by the surgeon's preferred method for reducing porosity and placed retrograde by syringe, followed by pressurization proximally. Because of the consistency with which the cement mantle can be attained utilizing the Exactech Cemented Total Hip System and the excellent filling that is obtained using the described method, seldom is one standard pack of bone cement sufficient. One and one-half to two and one-half standard packs of cement are usually used.

The stem centralizer is placed by hand in the distal stem receptacle. The centralizer should not be tapped with a mallet. The femoral stem has been specially cleaned and prepared to allow optimal cement fixation. The surgeon should minimize handling the stem portion below the collar.

The selected amount of anteversion, usually 10 degrees, is held while the stem is placed into the femoral canal (Fig. 25). Femoral stem placement by hand has the advantage of avoiding the long lever arm of mechanical positioners which results in additional motion of the stem during cement polymerization. If desired, final seating of the femoral stem may be accomplished by placing the femoral stem impactor in the small lateral receptacle of the stem and tapping gently with the mallet. The stem impactor should be held parallel to the femoral neck. Excess cement is cleared and the cement is allowed to polymerize.

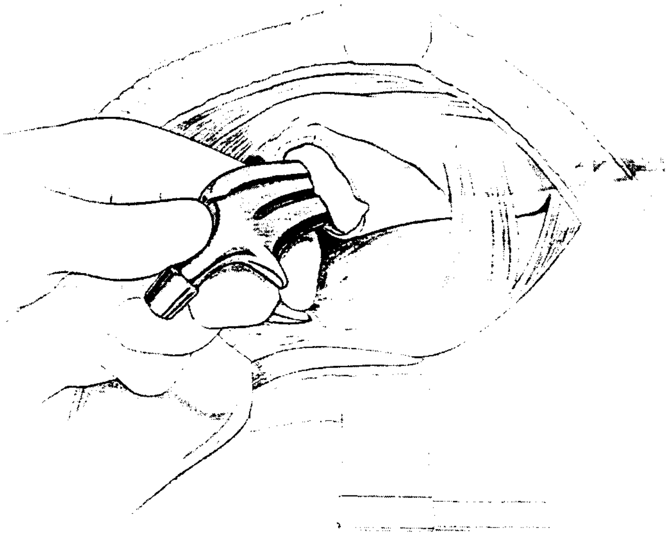


Figure 25: Femoral stem insertion

Further Trial Reduction

If the surgeon desires, he may place the trial femoral head component on the femoral neck and carry out another trial reduction to examine length and stability.

The tapered femoral neck is cleaned and dried and the selected femoral head component is placed and, using the femoral head impactor, struck with two or three moderate mallet blows (Fig. 26).

The femoral head component may be placed on the stem prior to stem insertion if the surgeon desires and is satisfied with the length determination.

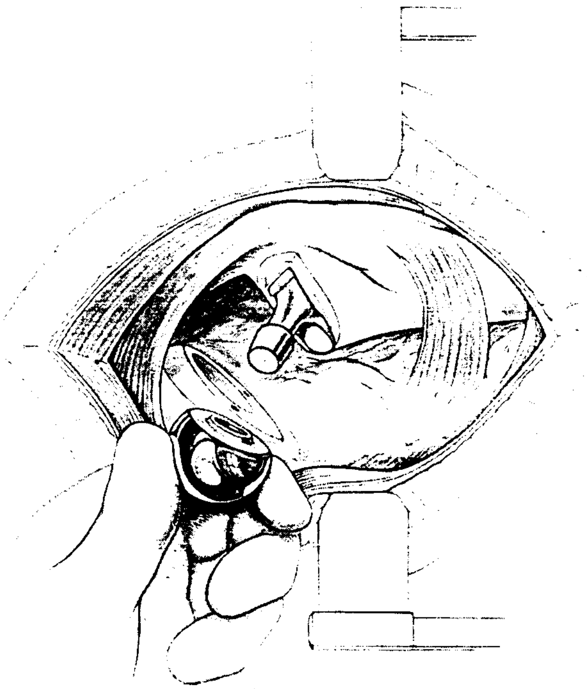


Figure 26: Femoral head placement

Final Reduction

The wound is thoroughly irrigated and all debris removed, paying particular attention to the acetabular component. The hip is then gently reduced and length, motion, and stability checked again.

Closure is performed by the method the surgeon prefers. When utilizing the posterior approach, reattachment of the piriformis muscle to the soft tissues of the posterior superior corner of the greater trochanter may enhance stability. If the gluteus maximus tendon has been released, it is repaired. A closed suction drainage system should be used.

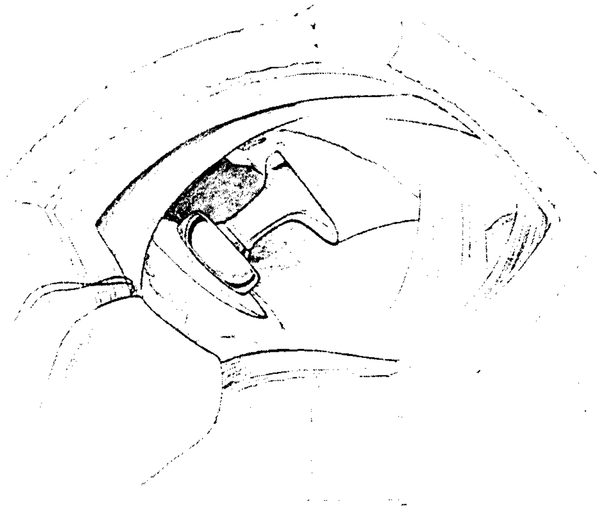


Figure 27: Final reduction

Postoperative X-rays

In evaluating postoperative X-rays, the surgeon should remember that the metal shell of the acetabular component is normally contained completely within the bony acetabulum and is more abducted than the face of the high molecular weight polyethylene component.

To avoid drilling holes in the superior portion of the acetabular polyethylene and the attendant weakening that this causes, metal markers have not been placed in the polyethylene portion of the Exactech Cemented Acetabular Component. If the surgeon examines the X-rays carefully, the lucent area of the polyethylene extending beyond the acetabular metal shell usually can be seen. If it cannot, the surgeon may place an acetabular template over the implanted acetabular component to show the actual femoral head coverage by the polyethylene portion of the acetabular component.

REFERENCES

1. **Chandler, H.P., Reineck, F.T., Wixson, R.L., and McCarthy, J.C.:** "Total Hip Replacements in Patients Younger Than Thirty Years Old." J. Bone and Joint Surg. 63-A:1426, 1981.

2. **Collis, D.K.:** "Cemented Total Hip Replacement in Patients Who Are Less Than 50 Years Old." J. Bone and Joint Surg. 60-A:353, 1984.

3. **Crowninshield, R.D., Brand, R.A., Johnston, R.C., and Milroy, J.C.:** "An Analysis of Femoral Component Stem Design in Total Hip Arthroplasty." J. Bone and Joint Surg. 62-A:68, 1980.

4. **Crowninshield, R.D., Brand, R.A., Johnston, R.C., and Milroy, J.C.:** "The Effect of Femoral Stem Cross-Sectional Geometry on Cement Stresses in Total Hip Reconstruction." Clin. Orthop. 146:71, 1980.

5. **Kay, A., Davison, B., Bradley, E., and Wagstaff, S.:** "Hip Arthroplasty: Patient Satisfaction." Br. J. Rheum. 22:243, 1983.

6. **Kwok, B.M., Lim, O.K., Kim, Y.Y.:** "Study of the Effect of Cement Thickness in an Implant by Finite Element Stress Analysis." Int. Orthop. 7:315, 1978.

7. **Levy, R.N., Volz, R.G., Kaufer, H., Matthews, L.S., Capozzi, J., Sturm, P., and Sherry, H.:** "Progress in Arthritis Surgery." Clin. Orthop. 200:299, 1985.

8. **Miller, G.J., Petty, R.W., Piotrowski, G.:** "A Comparison of Acetabular Strain Changes Following Ti6A14V and CoCr Metal Backed Component Implantation." Transactions of the 32nd Annual Meeting of the Orthopaedic Research Society, No. 11:469, 1986 (abs).

9. **Nevitt, M.C., Epstein, W.C., Masem, M., and Murr, W.R.:** "Work Disability Before and After Total Hip Arthroplasty." "Assessment of Effectiveness in Reducing Disability." Arth. Rheum. 27:310, 1984.

10. **Oh, I., and Harris, W.H.:** "Proximal Strain Distribution in the Loaded Femur." J. Bone and Joint Surg. 60-A:75, 1978.

11. **Oh, I., Sander, T.W., and Treharne, R.W.:** "Acetabular Cup Groove and Pod Design and Its Effect on Cement Fixation in Total Hip Arthroplasty." Clin. Orthop. 189:308, 1984.

12. **Ranawat, C.S., Atkinson, R.E., Salvati, E.A., and Wilson, P.D.:** "Conventional Total Hip Arthroplasty For Degenerative Joint Disease in Patients Between the Ages of Forty and Sixty Years." J. Bone and Joint Surg. 60-A:745, 1984.

13. **Tapadaya, D., Walker R.H., and Shurman, D.J.:** "Predictions of Outcome of Total Hip Arthroplasty Based on Initial Post-Operative Radiographic Analysis." Clin. Orthop. 186:5, 1984.

M ◆ C ◆ S

MODULUS COMPATIBILITY AND
MULTIPLANE STABILITY

Operative Technique

Porous Coated Total Hip Arthroplasty

• • • • • • • • • • • • • •

Exactech
INC.

MCS™ Porous Coated Total Hip System

• •

Surgical Technique

by

William Petty, M.D.

Prosthesis and Instrument Design by:

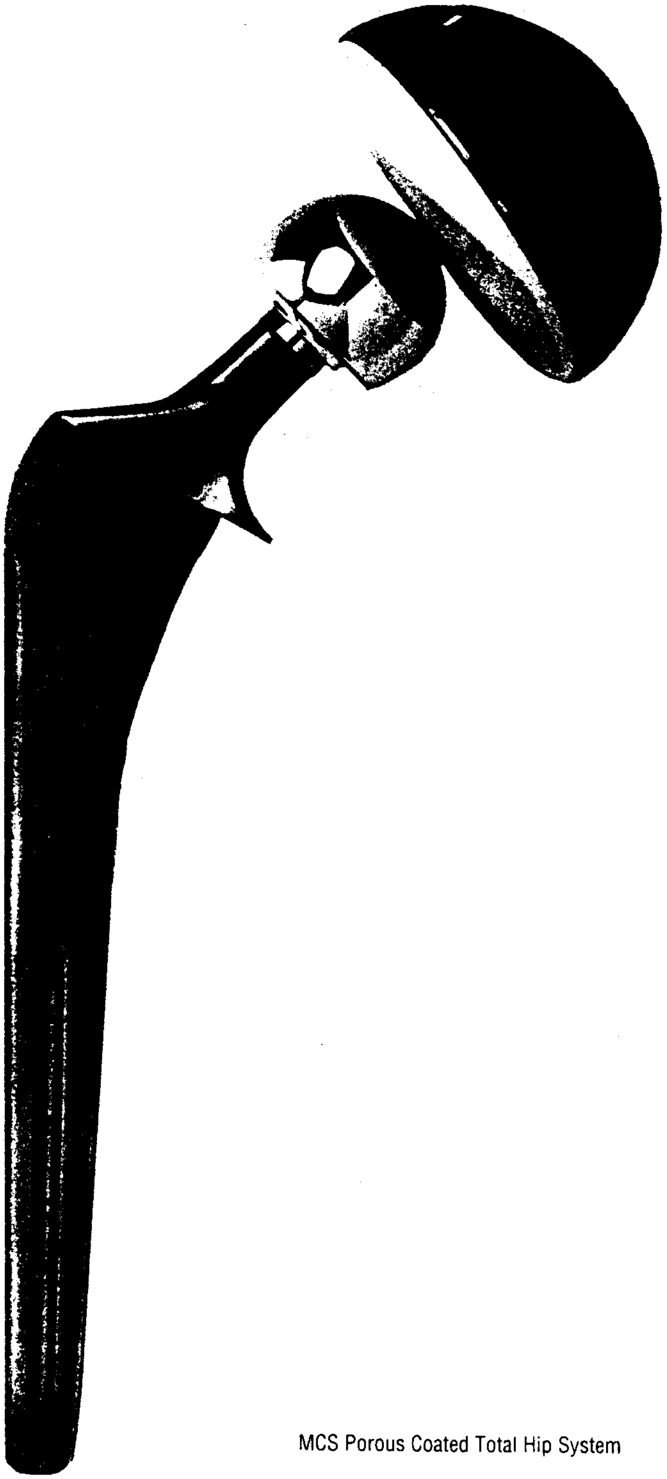
William Petty, M.D.
Professor and Chairman
Department of Orthopaedics
University of Florida College of Medicine
Gainesville, Florida

Gary J. Miller, Ph.D.
Associate Professor
Department of Orthopaedics
University of Florida College of Medicine
Gainesville, Florida

© 1991 Exactech, Inc.

EXACTECH MCS POROUS-COATED HIP SYSTEM

The design of the Exactech MCS Porous-Coated Hip System is based on the accumulated clinical and laboratory research of many investigators to achieve a state-of-the-art total hip arthroplasty reconstruction. The design goals for the prostheses have been to 1)minimize the two major problems associated with other porous-coated prostheses: thigh pain and abnormal bone remodeling 2)avoid unnecessary damage to the bone and its blood supply during femoral preparation and 3)provide instrumentation that facilitates reproducible implantation of the prostheses. The system consists of an acetabular shell and liner, screws for supplemental fixation of the acetabular shell, and a femoral stem. All Exactech femoral heads can be used with the femoral stem.



MCS Porous Coated Total Hip System

Acetabular Component

The MCS acetabular component consists of a titanium alloy shell and a polyethylene liner. The shell has both dome and peripheral screw holes to access the best pelvic bone stock. Peripheral screw holes accept 4.5mm titanium screws and dome holes accept 6.5mm titanium screws. Both screw configurations are designed to countersink the screw within the metal shell. The shell has been designed to provide optimum stress transfer of loads from prosthesis to bone. The internal configuration of the shell provides for versatility in placement of the 15 degree sloped roof of the polyethylene liner. The locking mechanism between the shell and liner allows for easy assembly and disassembly, yet maintains excellent locking integrity. Each shell is oversized .6mm to its corresponding reamer which is designed to create a hemispherical cavity for shell placement. The shell positioner/impactor instrument provides for complete abduction-adduction, anteversion-retroversion and rotational control. Liners are available in 26mm, 28mm, and 32mm inner diameters. Table 1 states the relationship of shell size to liners and numbers of screw holes. Table 2 shows screw sizes.

SHELLS		LINERS		SCREW HOLES	
Size mm	Catalog Number	26mm ID	32mm ID	No. of 6.5 mm screw holes	Available w/ 4.5mm peripheral screw holes
44	PAS-44	L6-4448	N/A	6	NO
46	PAS-46			6	NO
48	PAS-48			6	NO
50	PAS-50	L6-5052	L2-5052	8	YES (4)
52	PAS-52			8	YES (4)
54	PAS-54	L6-5458	L2-5458	8	YES (4)
56	PAS-56			8	YES (4)
58	PAS-58			8	YES (4)
60	PAS-60	L6-6064	L2-6064	8	YES (4)
62	PAS-62			8	YES (4)
64	PAS-64			8	YES (4)
66	PAS-66	L6-6670	L2-6670	8	YES (4)
68	N/A				
70	PAS-70	L6-6670	L2-6670	8	YES (4)

Table 1: Shells

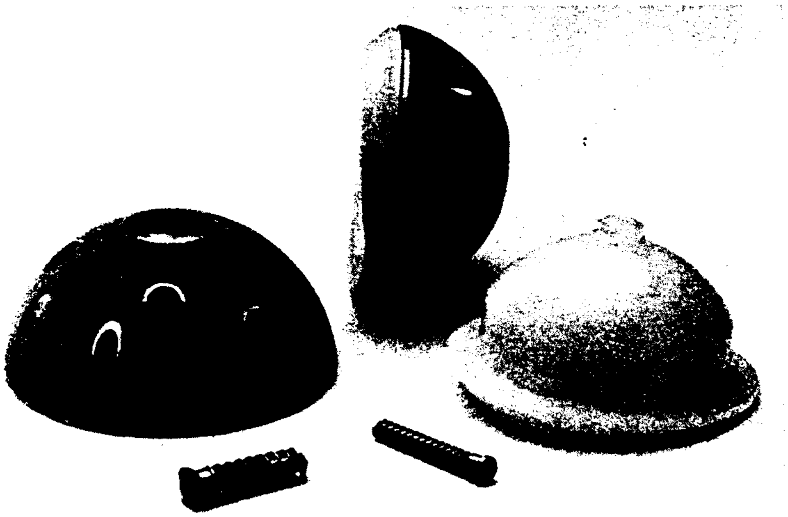
4.5 mm Screw

Catalog No.	Length
SC45-25	25mm
SC45-30	30mm
SC45-35	35mm
SC45-40	40mm
SC45-45	45mm
SC45-50	50mm

6.5 mm Screw

Catalog No.	Length
SC65-15	15 mm
SC65-20	20mm
SC65-25	25mm
SC65-30	30mm
SC65-35	35mm
SC65-40	40mm

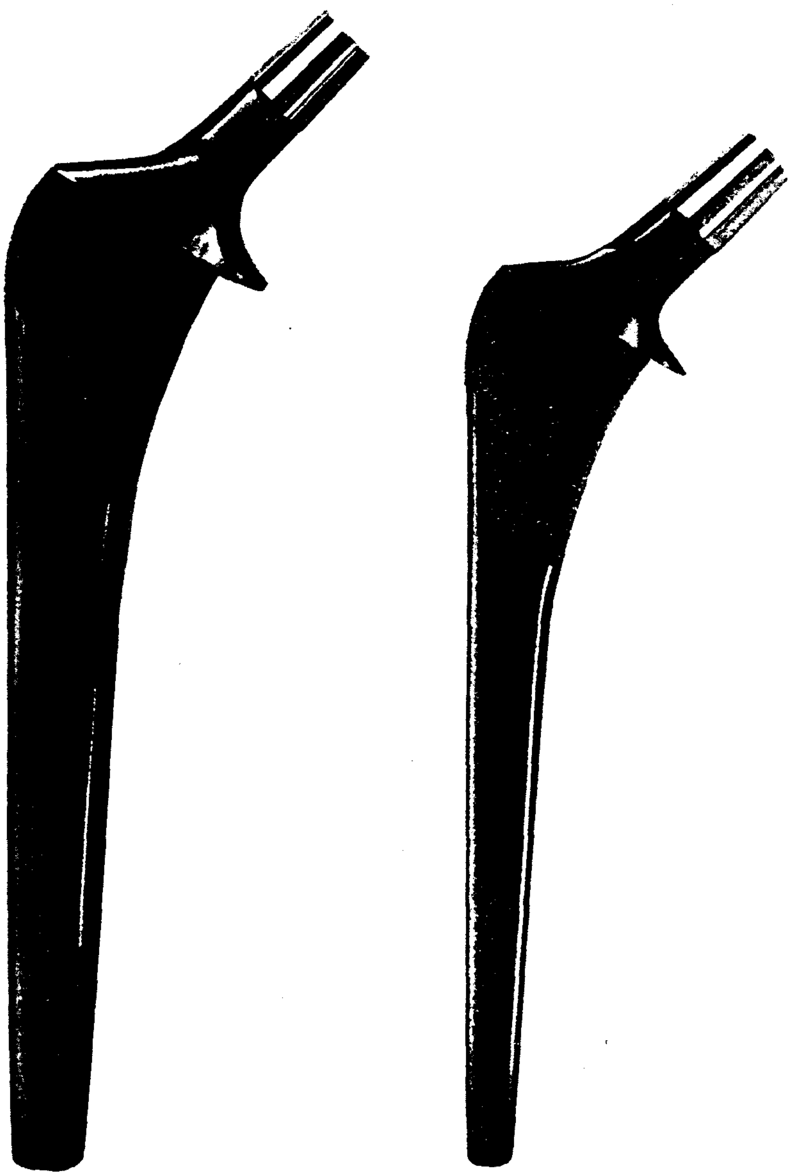
Table 2: Screws



Femoral Head

The Exactech Femoral Head is available in four neck lengths: short (-5mm), standard (0), long (+5mm), extra long (+10mm), and in three diameters: 26mm, 28mm, and 32mm (Table 4). The femoral head mates with the femoral stem by its precise internal taper (Fig. 1). A unique head and taper design produces a shorter taper sleeve in the longer neck lengths. This design reduces the possibility of dislocation caused by sleeve impingement.

Femoral Stem, representative small and large sizes



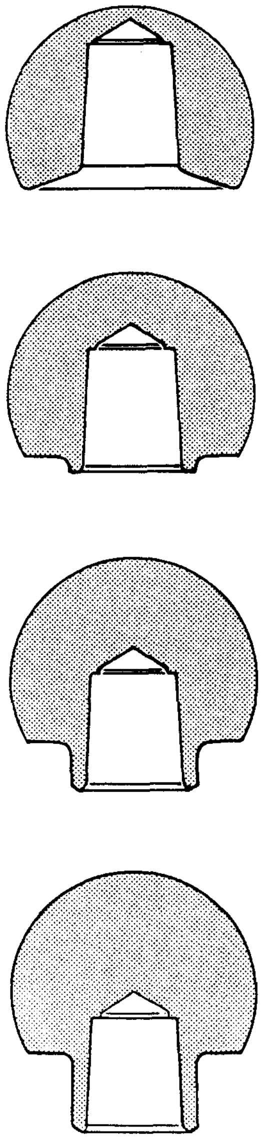


Figure 1: Femoral head components

Femoral Stem

The MCS femoral stem is designed to provide modulus compatibility and multiplane stability within the femur. The cross-sectional geometry of the stem is trapezoidal providing excellent proximal fill of the metaphyseal portion of the femur for better stress transfer to bone as well as maximum resistance to rotational forces. One of the design goals for the MCS stem was to eliminate the thigh pain that occurs with other press fit stems. The design provides increased proximal stress transfer and minimizes stress transfer in the distal stem. It tapers away from the bone gradually in its most distal portion to avoid a sudden change in stress level in the bone at the stem tip. The MCS stem is made of forged titanium alloy which is significantly more flexible than cobalt chrome. In addition, the larger sizes of the stem have channels on all sides to reduce stem stiffness. The amount of material removed increases as the stem size increases. This provides a more uniform flexibility of the stem throughout the range of sizes (Table 3). The reduced stiffness of the MCS stem is also intended to limit the incidence of proximal bone resorption due to stress shielding.

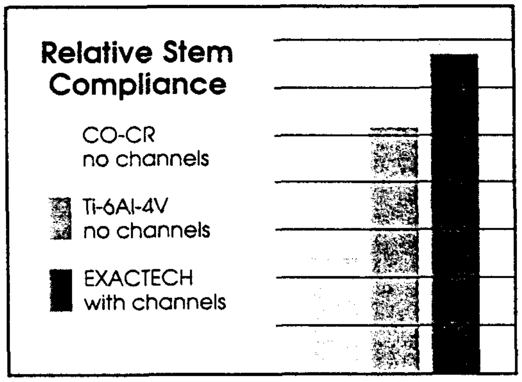


Table 3: Enhanced stem flexibility resulting from titanium alloy and distal stem channels.

Stem Size	1	2	3	4	5	6	7	8	9	10
Stem Length	130	135	140	145	150	155	160	165	170	175
Effective Neck Lengths: Short Neck (-5mm) S	25	25	25	30	30	30	30	35	35	35
Medium Neck (0mm) M	30	30	30	35	35	35	35	40	40	40
Long Neck (+5mm) L	35	35	35	40	40	40	40	45	45	45
Extra Long Neck (+10mm) XL	40	40	40	45	45	45	45	50	50	50

Table 4: MCS Stem sizes and neck lengths

Femoral Stem

The MCS femoral stem is designed to provide modulus compatibility and multiplane stability within the femur. The cross-sectional geometry of the stem is trapezoidal providing excellent proximal fill of the metaphyseal portion of the femur for better stress transfer to bone as well as maximum resistance to rotational forces. One of the design goals for the MCS stem was to eliminate the thigh pain that occurs with other press fit stems. The design provides increased proximal stress transfer and minimizes stress transfer in the distal stem. It tapers away from the bone gradually in its most distal portion to avoid a sudden change in stress level in the bone at the stem tip. The MCS stem is made of forged titanium alloy which is significantly more flexible than cobalt chrome. In addition, the larger sizes of the stem have channels on all sides to reduce stem stiffness. The amount of material removed increases as the stem size increases. This provides a more uniform flexibility of the stem throughout the range of sizes (Table 3). The reduced stiffness of the MCS stem is also intended to limit the incidence of proximal bone resorption due to stress shielding.

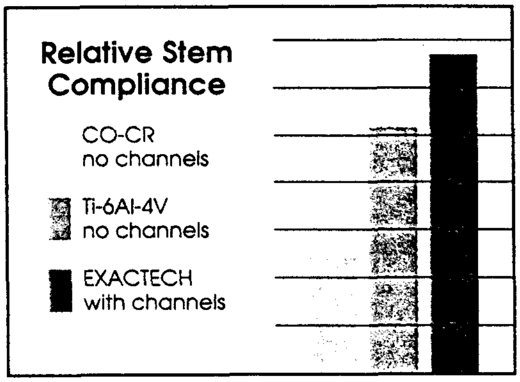


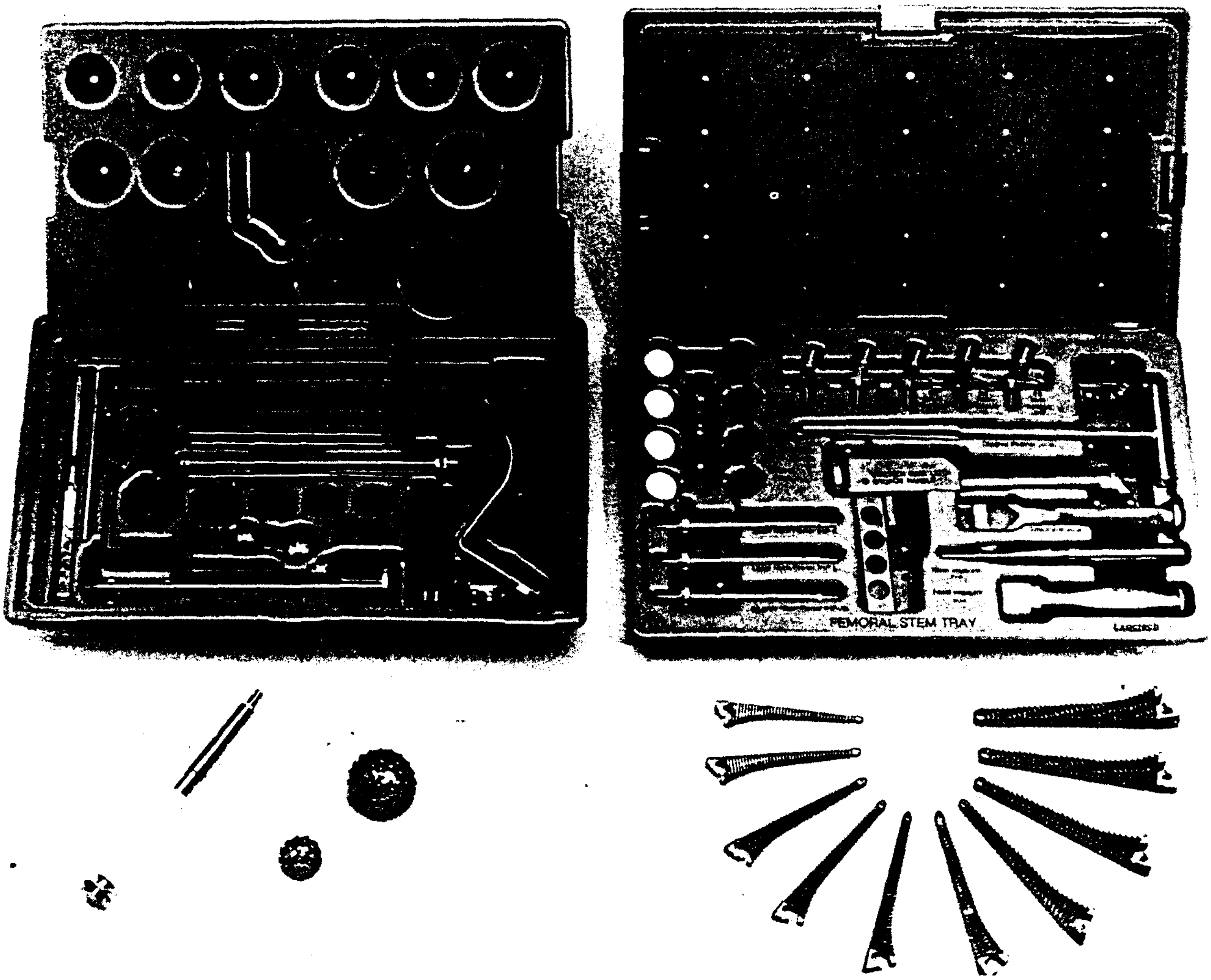
Table 3: Enhanced stem flexibility resulting from titanium alloy and distal stem channels.

Stem Size	1	2	3	4	5	6	7	8	9	10
Stem Length	130	135	140	145	150	155	160	165	170	175
Effective Neck Lengths: Short Neck (-5mm) S	25	25	25	30	30	30	30	35	35	35
Medium Neck (0mm) M	30	30	30	35	35	35	35	40	40	40
Long Neck (+5mm) L	35	35	35	40	40	40	40	45	45	45
Extra Long Neck (+10mm) XL	40	40	40	45	45	45	45	50	50	50

Table 4: MCS Stem sizes and neck lengths

Instrumentation

The MCS instrumentation is integrated with instrumentation for the Exactech Cemented Total Hip System, permitting the surgeon to switch easily from one system to another, even intraoperatively. The acetabular instruments differ between the two systems only in the acetabular positioners and impactors and the instruments necessary for screw and liner placement for the MCS socket. The femoral instruments differ in that 1)no reamers are used for the MCS stem 2)each system has a unique set of precision broaches. The modular Ultem™ instrument trays with labeling for instruments provide durable and efficient housing for the instrumentation system.



MCS basic femoral and acetabular instrument trays with broaches and representative acetabular reamers and handle displayed in foreground.

MCS Acetabular Instruments and Trials

Acetabular reamer heads are sized in two millimeter increments from 42 to 70 millimeters. The acetabular shell trials are sized exactly to the nominal reamer size for easy placement and visualization of bone contact through the visualization holes. The acetabular component is sized 0.6 millimeters larger than nominal reamer size to provide a tighter fit. Some surgeons prefer to under ream an additional two millimeters, particularly when a larger size socket is being implanted or when the bone is not especially dense. This provides for a tighter fit of the socket. The socket positioner/impactor consists of the impactor, a modular Ultem™ octagon, and the modular guide block and pins. The acetabular cup positioner/impactor provides the surgeon with complete multiplane control of the socket during implantation.

Screw Placement System

The screw placement system consists of 3.2 millimeter drill bits for use with the peripheral 4.5 millimeter screws, and both 3.2 and 4.5 millimeter flexible drill bits, either of which can be used for the 6.5 millimeter dome screws depending on the surgeon's preference and the hardness of the bone. A single screw driver handle is used with modular shafts: a straight shaft places either type screw, and a universal shaft places the 6.5 millimeter dome screws. Both 3.2 and 4.5 millimeter drill guides are available to assist in drilling the dome holes. Liner trials are available to check final positioning of the polyethylene liner before impacting the liner into place.

MCS Femoral Instruments and Trials

The Femoral Instrument System consists of the femoral neck osteotomy guide, a box osteotome, a T-handled tapered reamer, a broach handle and ten size-specific femoral broaches, femoral neck planers, a stem impactor, and a femoral head impactor. Size-specific collar neck trials and femoral head trials are used for trial reduction. All MCS femoral instruments are compatible with the Exactech Cemented Total Hip System except the broaches. The Femoral Instrument and Trial System allows preparation of the femur to provide precise fit of the MCS stem and facilitates consistent collar contact with the medial femoral neck cortex.

Preoperative Planning

Exactech MCS templates with 20 percent magnification are available for both the femoral and acetabular components. It may be helpful to template the contralateral hip as a guide if it is normal, but if final templating is not performed for the hip requiring arthroplasty it will be less likely to correspond to intraoperative findings where the final decision about prosthesis size selection is made.

The acetabular template should be placed in the position of the normal acetabulum to allow for maintenance of the subchondral bone. With the template held in the desired position, a mark is made at the center of rotation of the acetabular component. An estimate is made of the appropriate size femoral stem and that template is placed over the proximal femur. The surgeon selects the desired neck length. Normally, templating should be done for the standard (0) neck length. The center of rotation of the femoral head, which is marked with a cross-hatch, is placed over the center of rotation mark made during acetabular templating. Medial or lateral adjustments can be made along the lines extended from the cross-hatch in order to place the femoral stem appropriately over the femoral canal. If there is limb length inequality, appropriate adjustment for correction is made. When stem position has been established, a mark is made through the small holes medially and laterally along the femoral neck. A straight edge is used to connect the two dots, describing the line of femoral neck osteotomy. The distance from the superior portion of the lesser trochanter to the osteotomy line may be used intraoperatively as a guide for the level of osteotomy. During femoral templating, the surgeon should note the variance, if any, of the horizontal line extended from the center of rotation of the femoral head above or below the tip of the greater trochanter. This will be helpful during intraoperative assessment of extremity length.

This description will include the lateral decubitus position for total hip replacement, though the flexibility of the MCS Total Hip System allows for performance of the procedure in the supine position if the surgeon prefers. When the lateral position is used, it is important to have the patient well stabilized in position.

Surgical Approach

The MCS Total Hip System allows for performance of total hip arthroplasty through any standard approach for total hip replacement based on the surgeon's experience and preference. The posterior approach will be described. The skin incision is centered over the greater trochanter, extended distally along the proximal femur and extended proximally, curving it gently posteriorly (Fig. 2).

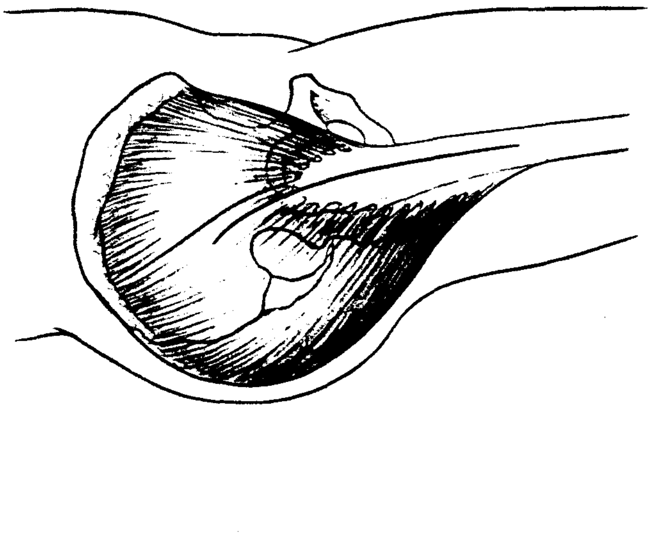


Figure 2: Skin Incision

The fascia lata is incised directly laterally over the greater trochanter and proximal femur and curved slightly posteriorly proximally. When the fibers of the gluteus maximus muscle are encountered, they are bluntly separated. The portion of the bursa and the adipose tissue over the short external rotators are excised or reflected to expose the short external rotator muscles. The short external rotators are incised along their attachment to the greater trochanter and gently stripped away from the capsule with a periosteal elevator (Fig. 3). The surgeon may wish to tag the piriformis tendon with a suture to allow for repair during closure.

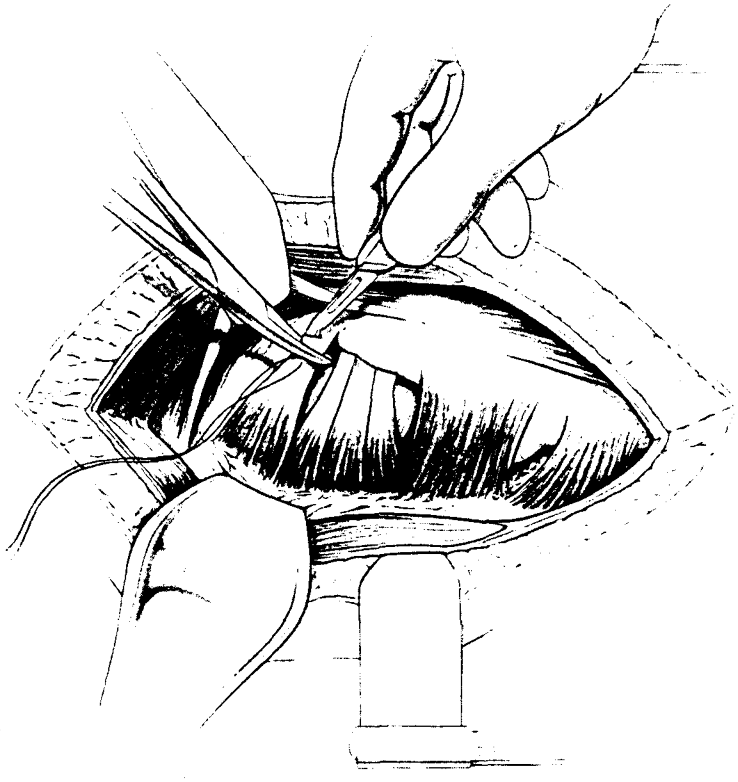


Figure 3: Incision of the External Rotators

Capsulotomy

A small blunt retractor may be placed medial to the posterior border of the gluteus medius muscle to expose the posterior border of the gluteus minimus. The interval should be established between the gluteus minimus muscle and superior capsule with a periosteal elevator. The elevator is used to expose the inferior capsule to approximately "six o'clock." It is helpful to place a cobra-type retractor between the gluteus minimus and superior capsule and around the inferior capsule, and to retract the short external rotators with a smooth blunt retractor (Fig. 4). Capsulotomy is performed across the superior capsule and extended posteriorly around to the inferior capsule. Both visualization and dislocation may be improved if a portion of the posterior capsule is excised.

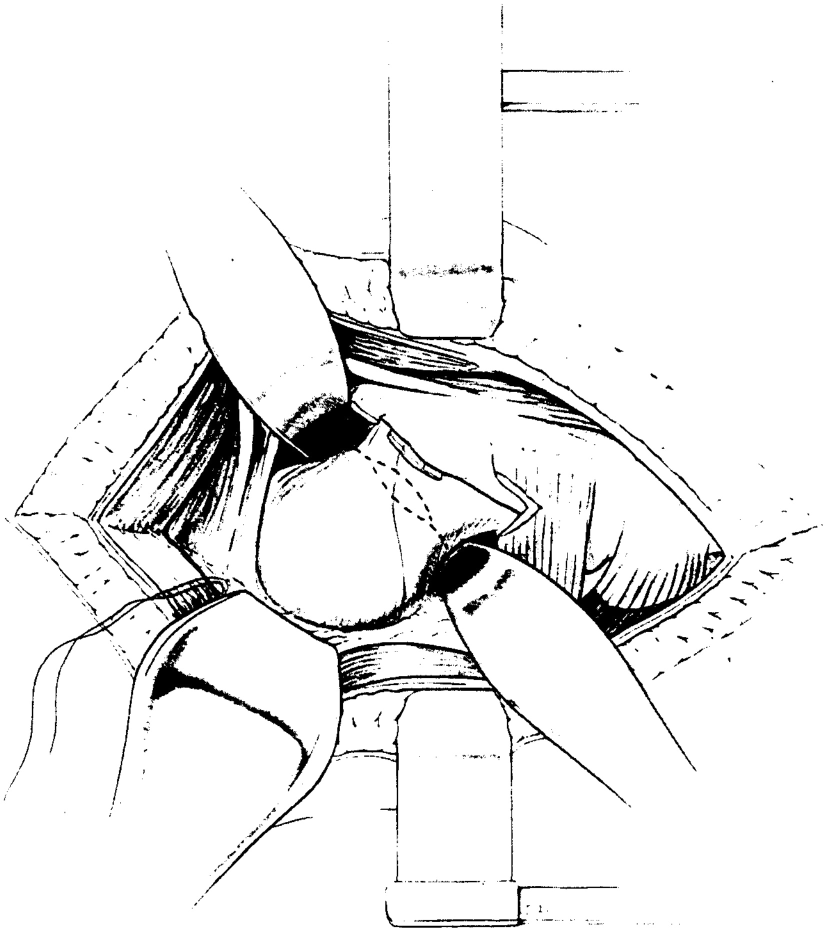


Figure 4: Capsulotomy

Dislocation

A large bone hook is placed around the femoral neck and with gentle internal rotation of the extremity and traction on the bone hook, the femoral head is dislocated posteriorly (Fig 5). Soft tissues are cleared along the intertrochanteric line to the proximal border of the lesser trochanter to improve exposure for selection of the neck osteotomy site. At times, exposure may be enhanced by release of the gluteus maximus tendon where it attaches to the femur (Fig. 6).

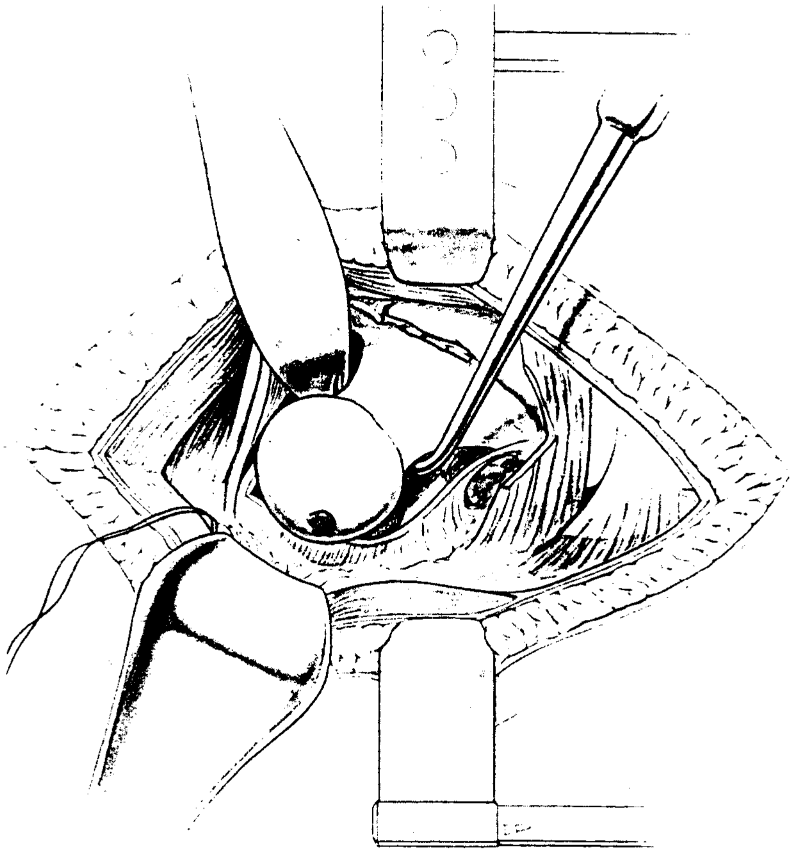


Figure 5: Dislocation

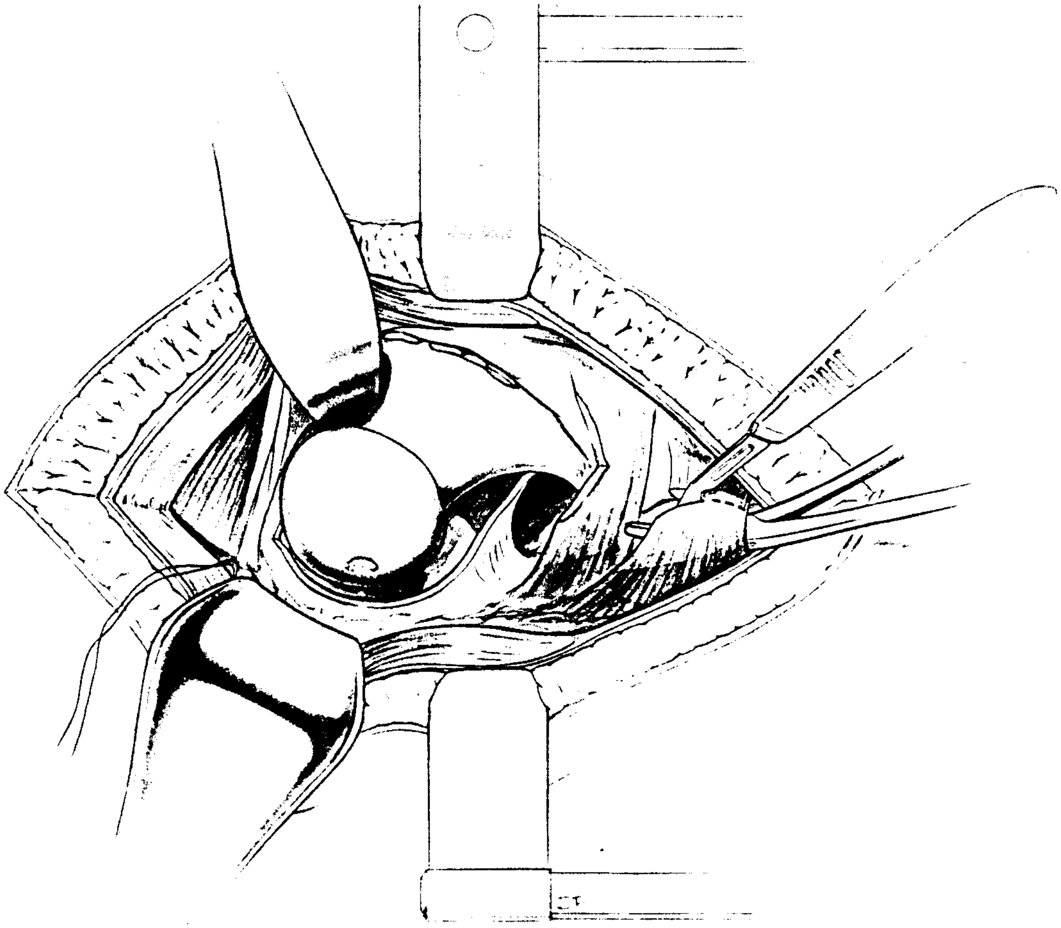


Figure 6: Optional release of gluteus maximus tendon

Osteotomy

The femoral neck osteotomy guide is aligned with the femur by either palpating the femur through the muscles or directing the guide toward the center of the popliteal fossa (Fig. 7).

The slot representing the selected neck length is centered over the center of rotation of the femoral head (Fig. 8).

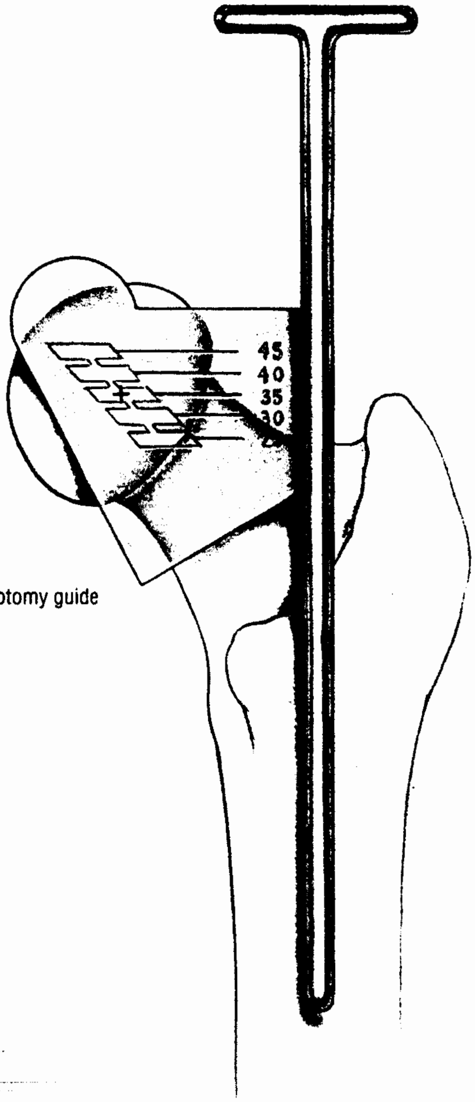


Figure 8: Alignment of neck osteotomy guide

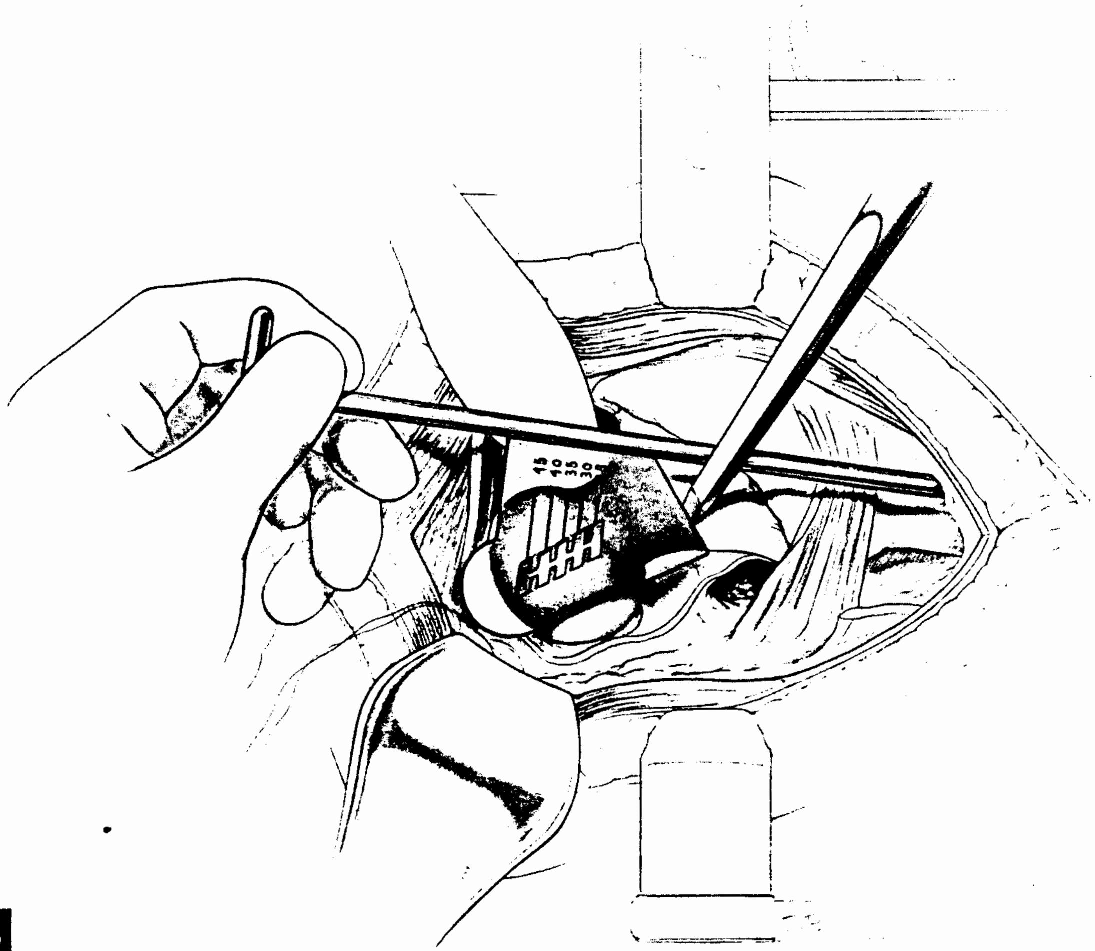


Figure 7: *Neck osteotomy guide placement*

The line extending from the slot over the center of the femoral head is correlated with the relationship of the tip of the greater trochanter to the center of rotation determined during preoperative templating. The appropriate neck resection level can also be determined by measuring the distance determined preoperatively between the superior edge of the lesser trochanter and the junction of the medial femoral neck and osteotomy surface of the neck osteotomy guide. The neck resection level is marked. An oscillating saw is used to perform the osteotomy (Fig. 9).

It usually will be necessary to cut the superior portion of the femoral neck along the medial border of the greater trochanter to avoid cutting into the greater trochanter.

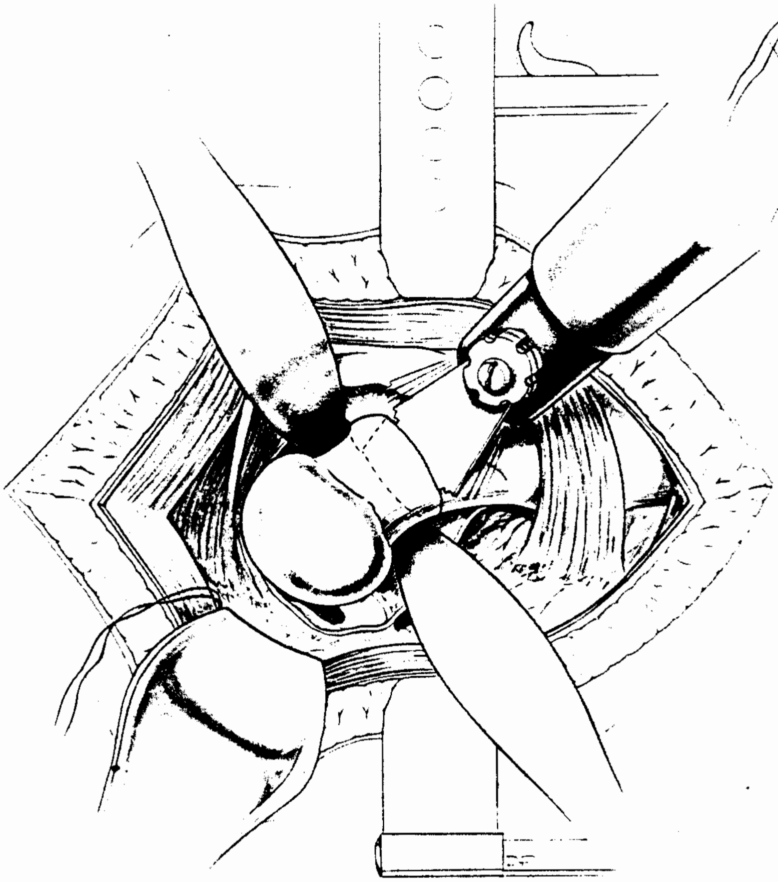


Figure 9: Femoral Neck Osteotomy

Optional Anterior Capsulotomy

A bone hook may be placed in the proximal femur to place tension on the remaining anterior capsule. A blunt clamp is then passed just anterior to the capsule and anterior capsulotomy performed (Fig. 10).

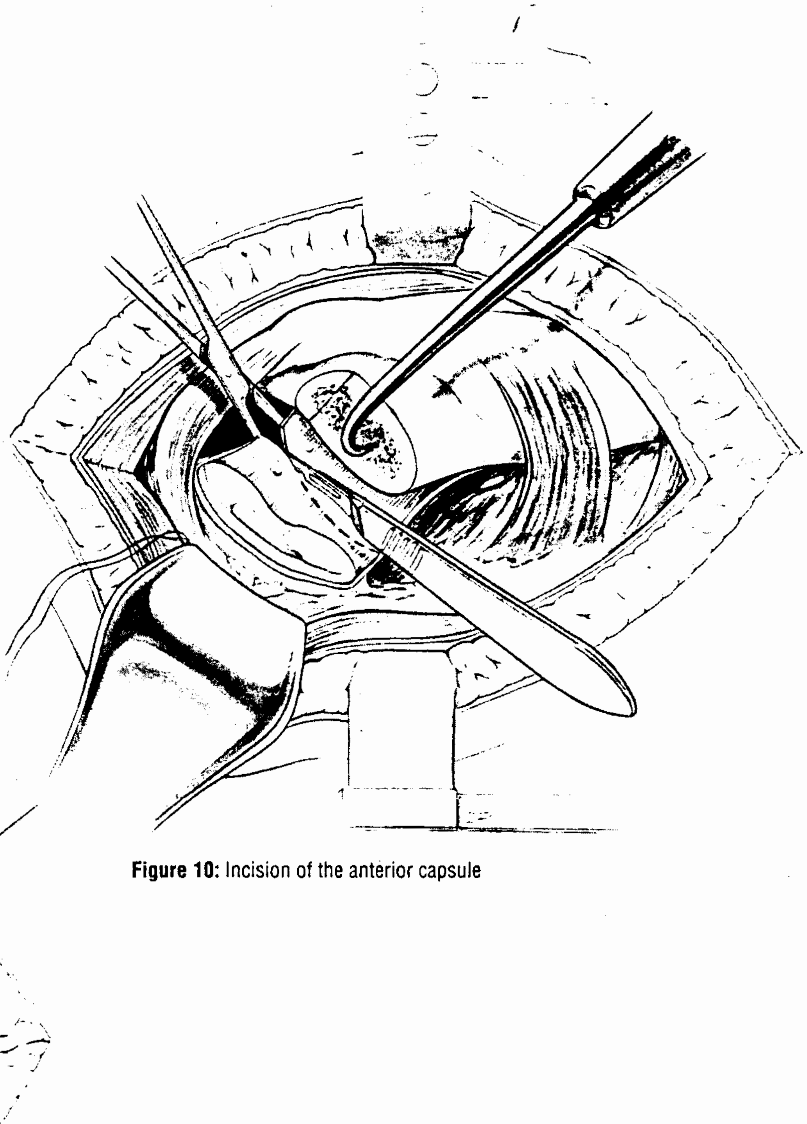


Figure 10: Incision of the anterior capsule

ACETABULAR PREPARATION

The superior acetabular retractor is placed utilizing drill bits. Blunt cobra retractors are placed anteriorly and inferiorly to the acetabulum. If necessary a smooth, blunt retractor should be used posteriorly (Fig.11).

Capsule around the edge of the acetabulum, labrum, and osteophytes are removed. Soft tissue, including any remaining articular cartilage or fibrocartilage is removed from the acetabulum. Normally, the acetabular reamer head selected for initial reaming is two or three sizes (4 or 6mm) smaller than the size templated. The surgeon may wish to direct initial reaming more medially with the first reamer, but subsequent reaming should be done in 45 degrees of abduction and 20 degrees of forward flexion (Fig. 12).

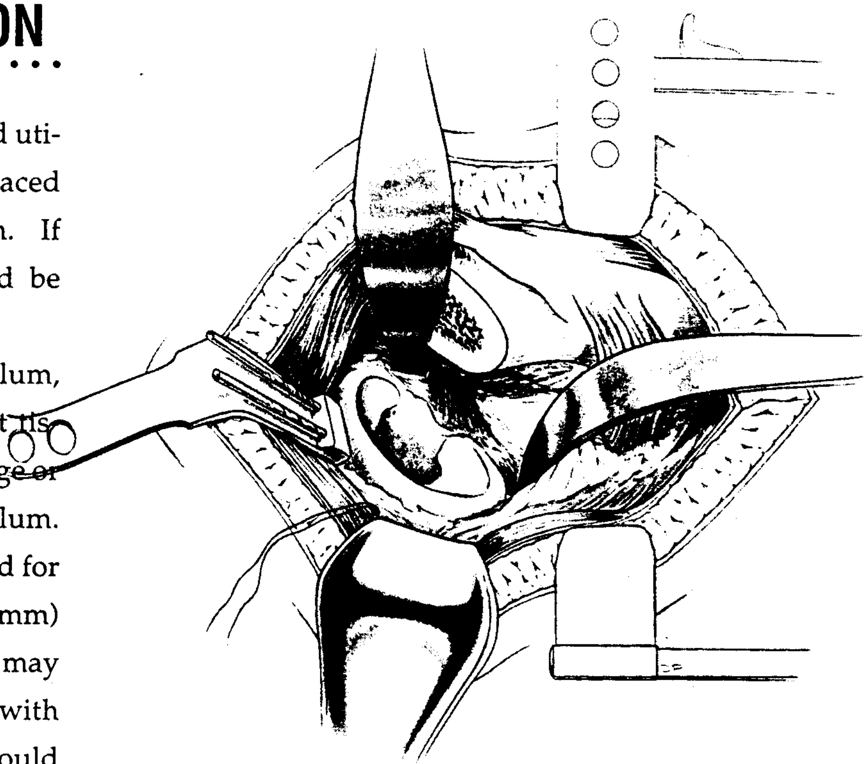


Figure 11: Placement of acetabular retractors

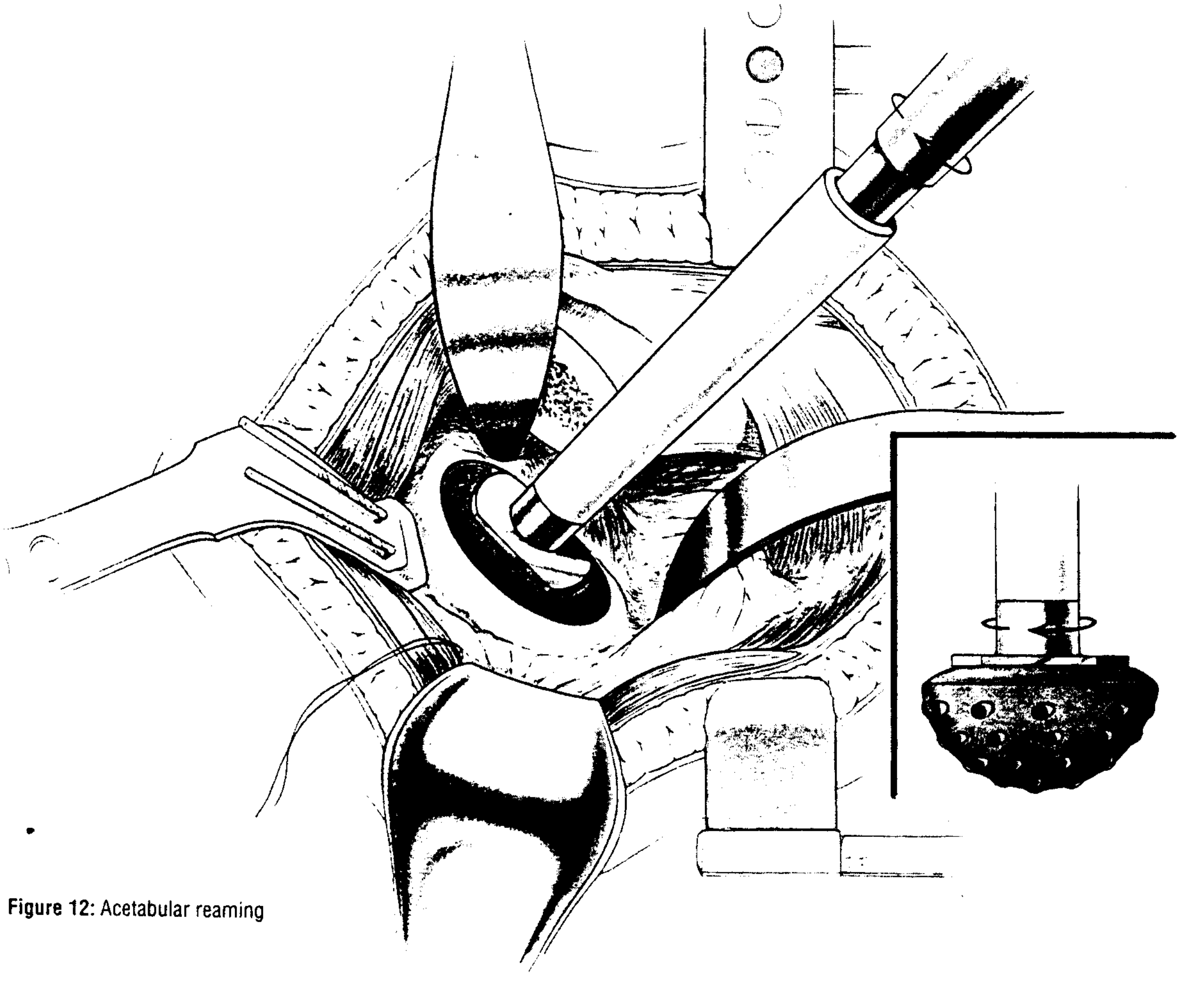


Figure 12: Acetabular reaming

When reaming is complete, the appropriate size socket shell trial is placed in the acetabulum and the quality of fit and bone apposition are checked (Fig. 13).

The acetabular shell trial is sized to nominal size and corresponds exactly to the reamer size so it will go into the reamed acetabulum relatively easily. The Exactech MCS socket shell is oversized 0.6mm, so when the socket shell is impacted it will provide an appropriately secure interference fit. Some surgeons prefer to "under ream" by an additional 2mm to provide additional interference fit, usually when the bone is relatively soft or the acetabulum is large. Any remaining osteophytes that might impede easy introduction of the socket shell are excised. After the appropriate socket shell size has been determined and evaluated, the trial component is removed and the acetabulum is further prepared by removing any remaining soft tissue. If cysts are present in the acetabulum, all soft tissue is cleared away and bone grafts are prepared from bone tissue collected during reaming (if it is free of soft tissue) or from the resected femoral head and neck and placed in the cysts or other bone defects.

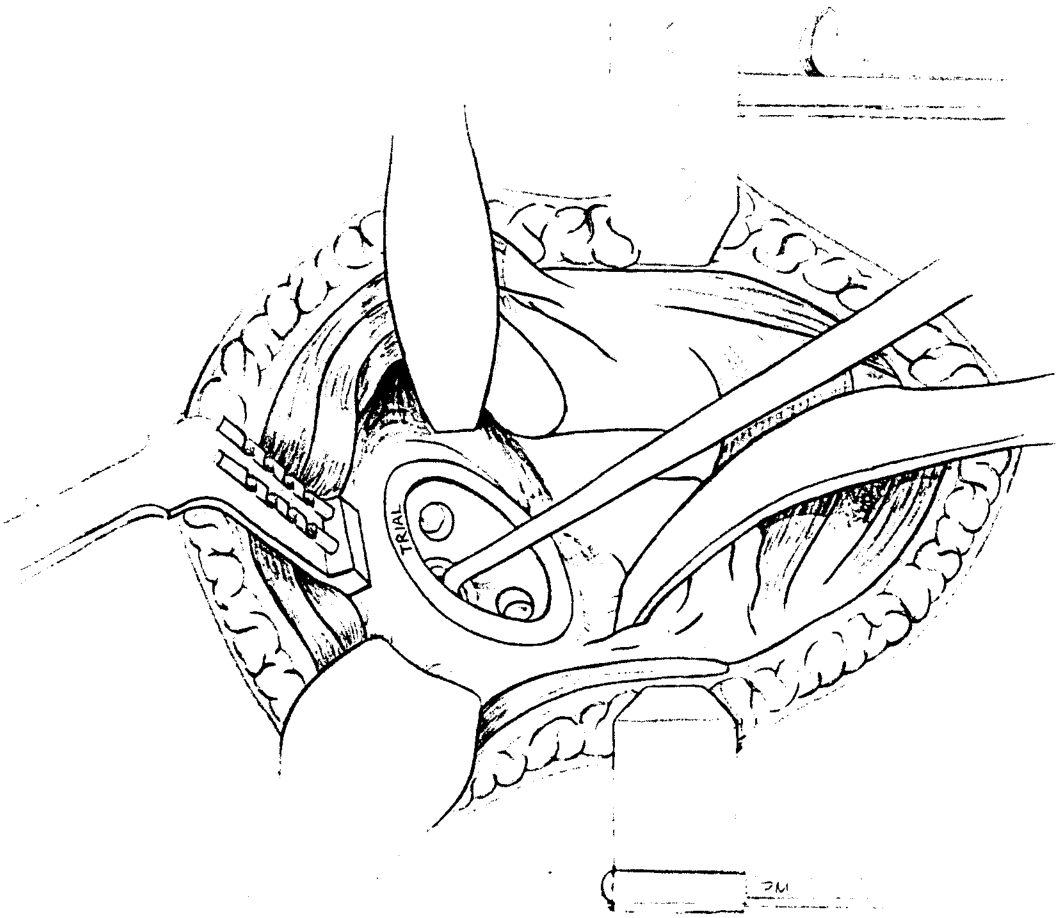


Figure 13: Trial checking bone apposition through holes

Shell Positioner Impactor

The positioner/impactor handle, alignment block, and guide pins are assembled. The block is attached with the "R" and "L" facing the surgeon. The vertical guide pin provides for 45 degrees of abduction when the pin is in the vertical position. Depending on whether it is a right or left hip, a pin is placed in the appropriate anteversion guide hole. The alignment will be 20 degrees anteversion when the pin is parallel with the axis of the body. The appropriate size octagon inserter is placed in the socket shell, then the assembled positioner/ impactor placed into the octagon and shell (Fig.14).

The shell positioner/impactor provides for complete abduction-adduction, anteversion-retroversion, and rotational control. There is direct impaction against the shell, thus creating firm, direct control of impaction.

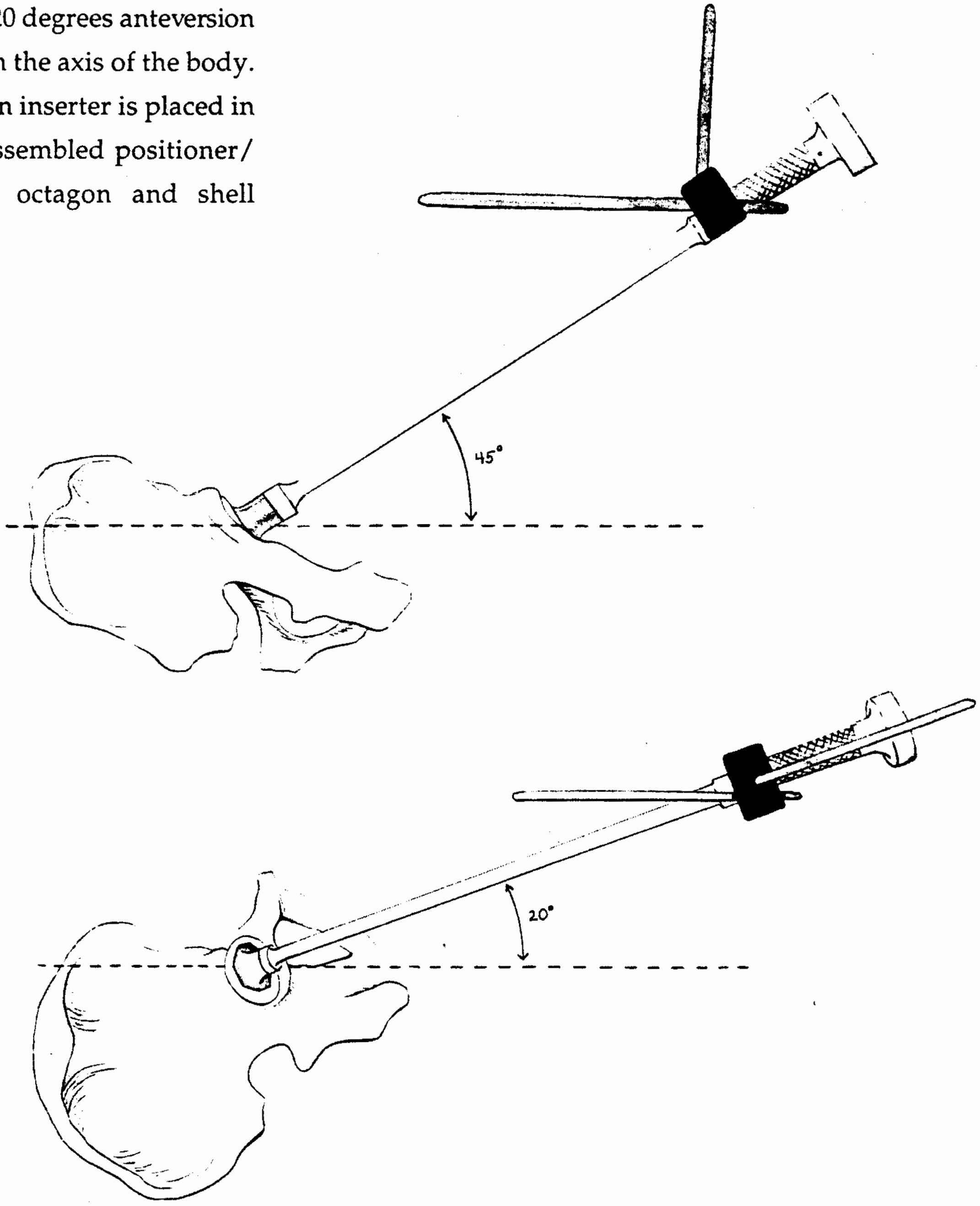


Figure 14: Acetabular impactor/positioner

Positioning the Shell

The peripheral screw holes of the shell are positioned in the location chosen by the surgeon. Normally, the best bone for peripheral screws is located superiorly or posterior-superiorly (Fig. 15).

The shell is impacted into place, normally in 45 degrees abduction and 20 degrees anteversion (Fig. 16). The inserter handle and octagon are easily removed from the shell, avoiding any unwanted forces on the shell. The dome screw holes and the polar hole are checked to confirm direct bone apposition (Fig.17).

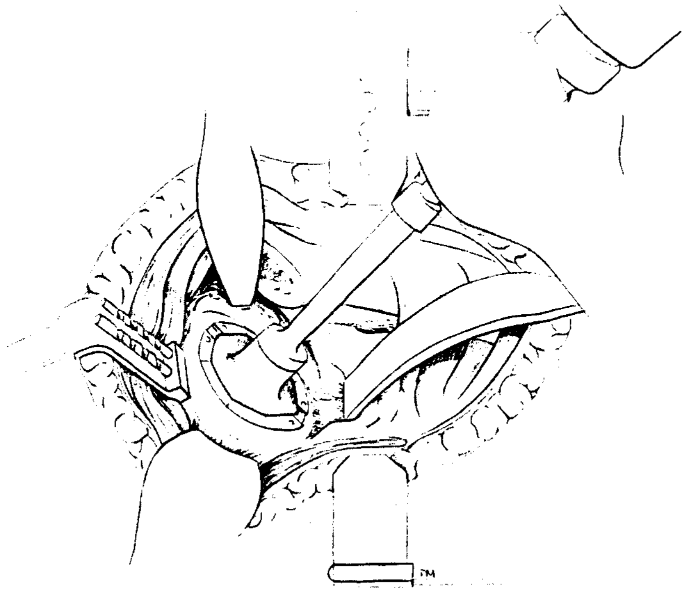


Figure 15: Acetabular prosthesis positioning

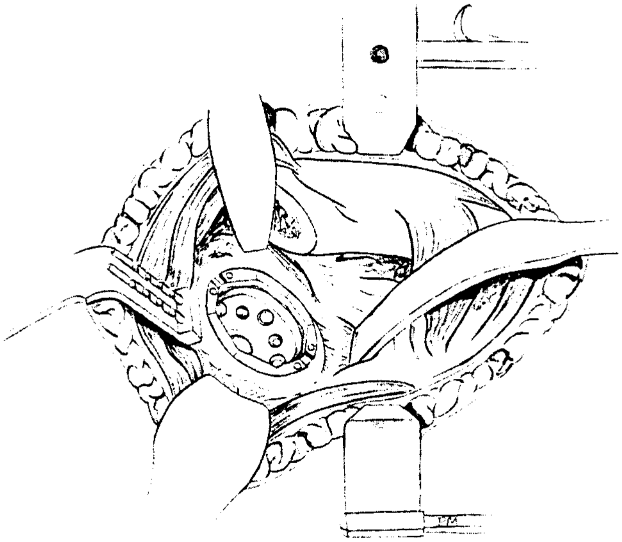


Figure 16: Final prosthesis placement

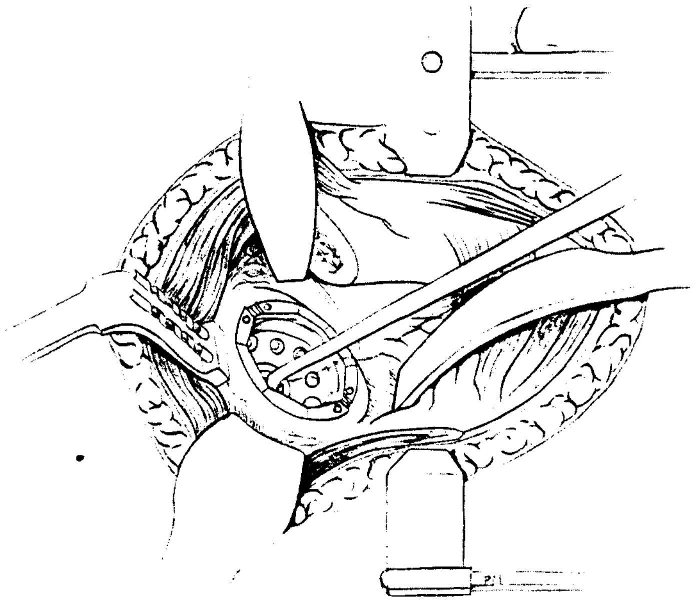


Figure 17: Checking socket fit against bone

Screw Placement

The Exactech MCS socket provides flexibility for supplemental screw fixation peripherally, centrally, or combined. Because of size constraints, peripheral screw holes are not available in socket shell sizes below 50mm. The drill system includes both straight and flexible 3.2mm drill bits and a flexible 4.5mm drill bit which is used for hard cortical bone. With softer bone, the 3.2 drill bits may be used for both the 4.5mm peripheral and 6.5mm dome screws. Peripheral screw holes are drilled with the 3.2mm drill bit, and the depth measured with the depth gauge (Fig. 18). Dome holes are normally drilled with the flexible drill bit. Use of the drill guide is essential to direct the drill hole appropriately and to avoid binding of the bit on the edge of the screw hole (Fig.19).

After the screw sites are selected and the holes drilled, the screws are placed. The screwdriver system includes either a standard or rachet screw driver handle that is used with all screwdriver shafts. The shafts include a straight driver for the peripheral 4.5mm screws and straight and universal shafts for the 6.5mm dome screws. Depending on screw placement, the universal shaft will normally be necessary for dome screws. Exactech MCS screwdriver shafts incorporate a twisted hexagon that creates an interference fit to retain and secure the screw to the shaft, making

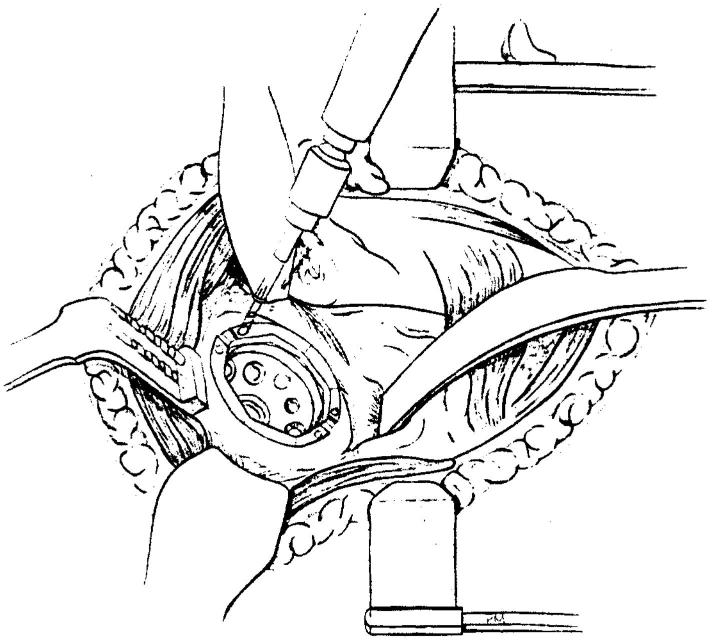


Figure 18: Drilling peripheral screw holes with straight drill bit

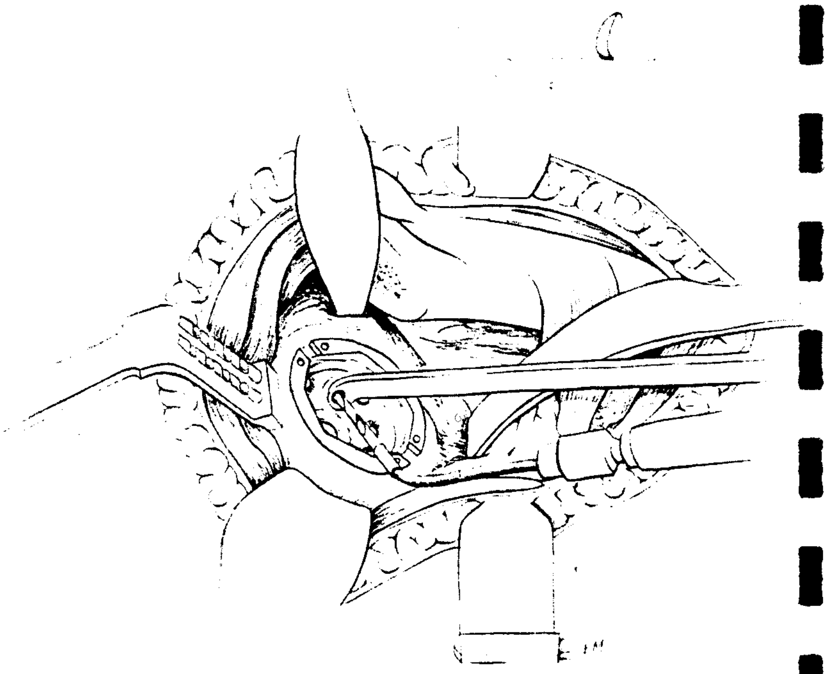


Figure 19: Drilling dome screw holes using flexible drill and guide

screw handling easier (Fig 20). Screws are placed assuring that all screw heads, whether peripheral or dome, are countersunk within the shell to avoid impingement against the polyethylene liner (Fig. 21).

The quadrant system should be used as an added safety measure during acetabular screw placement. That is, unless essential to provide stability, screws are not placed in the anterior superior and anterior inferior quadrants of the acetabulum (nor in the polar position) to avoid damaging the external iliac artery and vein and the obturator nerve, artery, and vein.

The quadrants are determined by an imaginary line running from the anterior superior iliac spine through the center of the acetabulum and bisected by a perpendicular line that creates the four quadrants. Placement of screws in the posterior superior or posterior inferior quadrants is relatively safe; also bone stock in these sites is better for screw placement. As an extra precaution, the sciatic notch area can be palpated posteriorly during drilling and screw placement. Because nerves and vessels may be injured in any quadrant, especially during plunging of the drill bit, care must be taken when any bone is drilled for placement of acetabular screws. Excessively long screws should be avoided.[1,2]

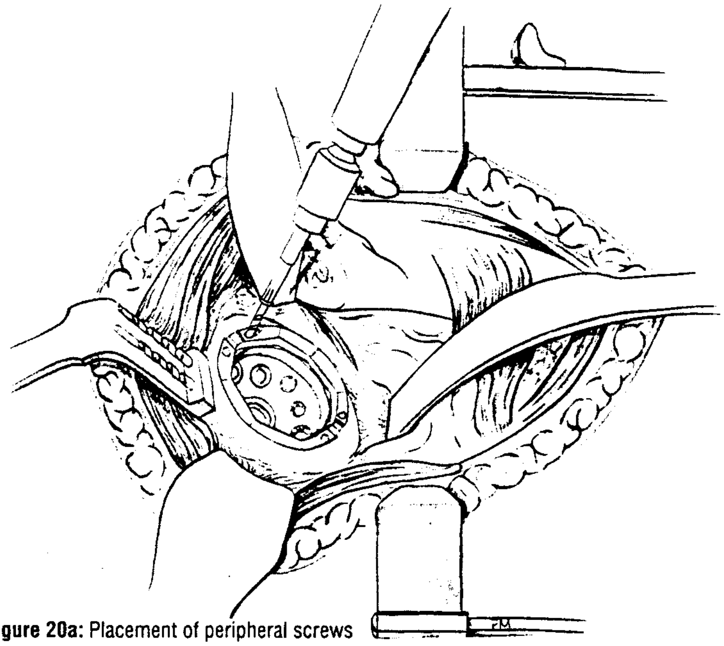


Figure 20a: Placement of peripheral screws

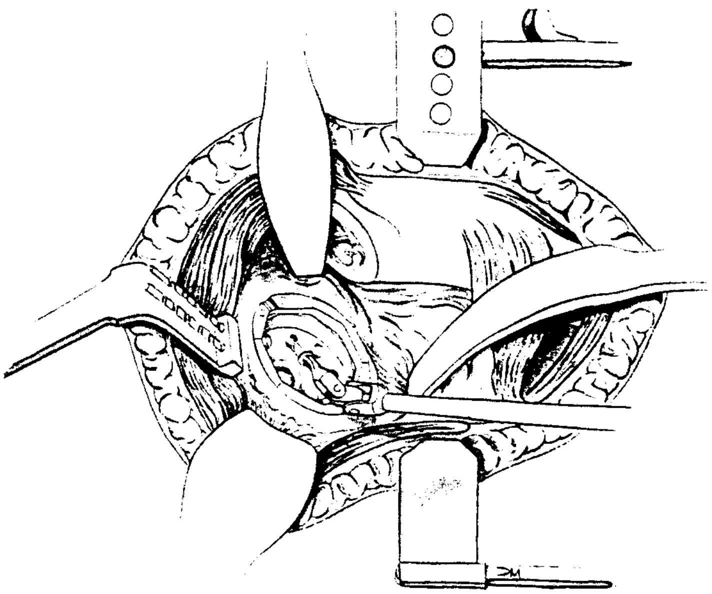


Figure 20b: Placement of dome screws

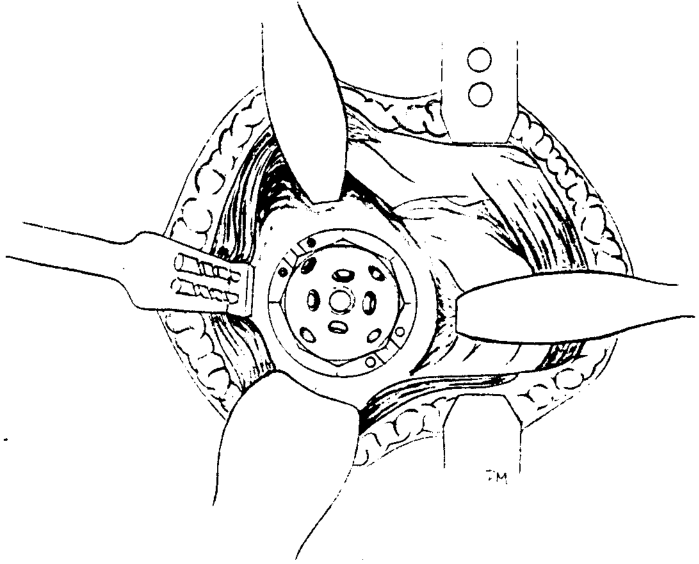


Figure 21: Final shell placement with dome and peripheral screws in place

Socket Liner Placement

The polyethylene liner is normally placed with the extended roof superiorly or postero-superiorly but it may be rotated to the position that provides the best stability (Fig. 22). The acetabular shell has a reference mark at each angle of its internal octagon and the liner has two scalloped notches on its outer rim. Aligning either of the notches with any of the reference marks will assure that the shell and liner are in the correct configuration for liner insertion and impaction. When the rotational position of the liner is established, the socket pusher/impactor is placed in the liner and the liner locked with a light blow with a mallet (Fig. 23). The liner must be fixed rotationally prior to impacting it. If it is not, the liner will not lock. The rim of the liner is inspected to assure complete seating of the liner against the shell.

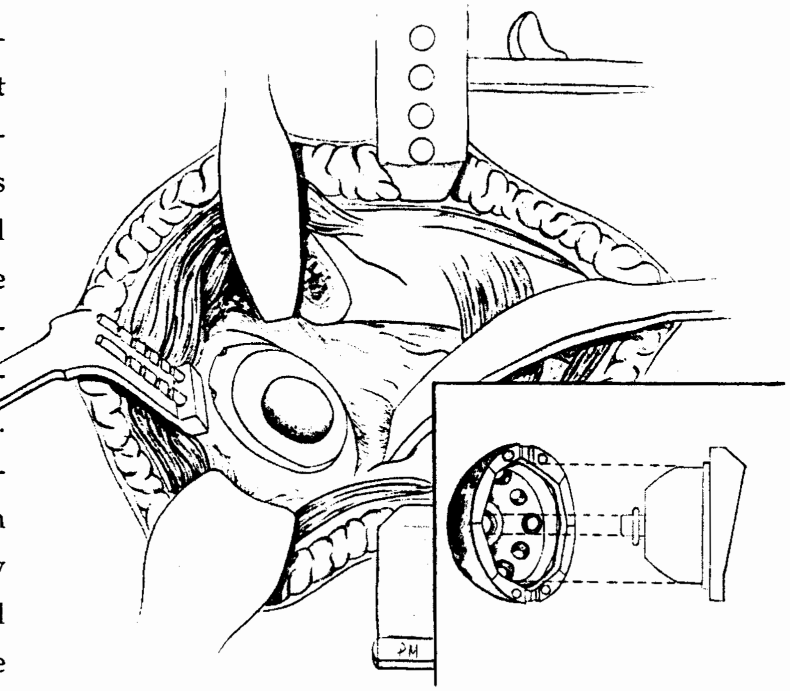


Figure 22: Shell and liner showing octagon and fit

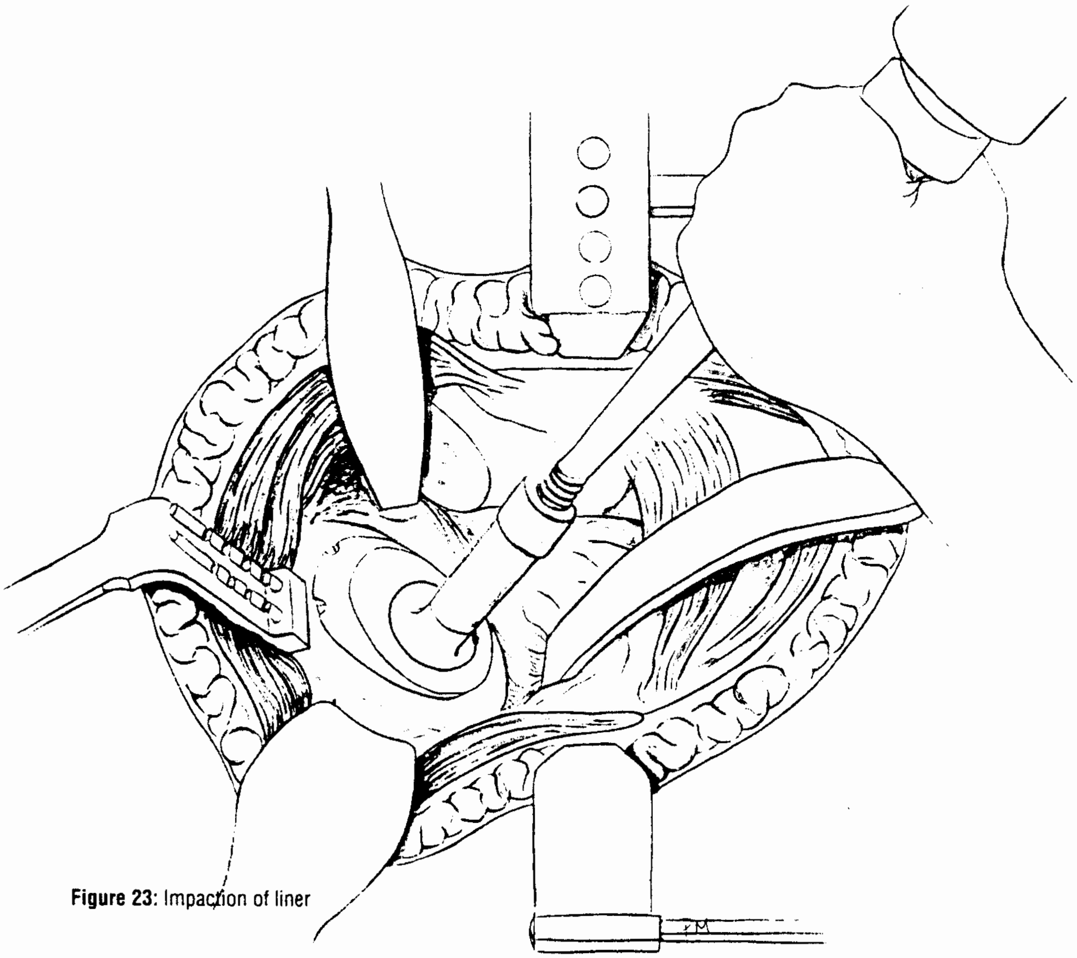


Figure 23: Impaction of liner

FEMORAL PREPARATION

Sizing established during preoperative templating is only a guide. Final determination of prosthesis size is made intraoperatively with the precision broaching system. A hip skid or similar retractor is placed to elevate the proximal femur. The box osteotome is used to remove any remaining lateral portion of femoral neck and medial cortical portion of greater trochanter to allow straight entry into the femoral canal (Fig. 24).

Initial entry into the femoral canal is made with the T-handled tapered reamer (Fig. 25). It may be helpful in establishing direction to palpate the proximal femur through the muscles during insertion of the tapered reamer.

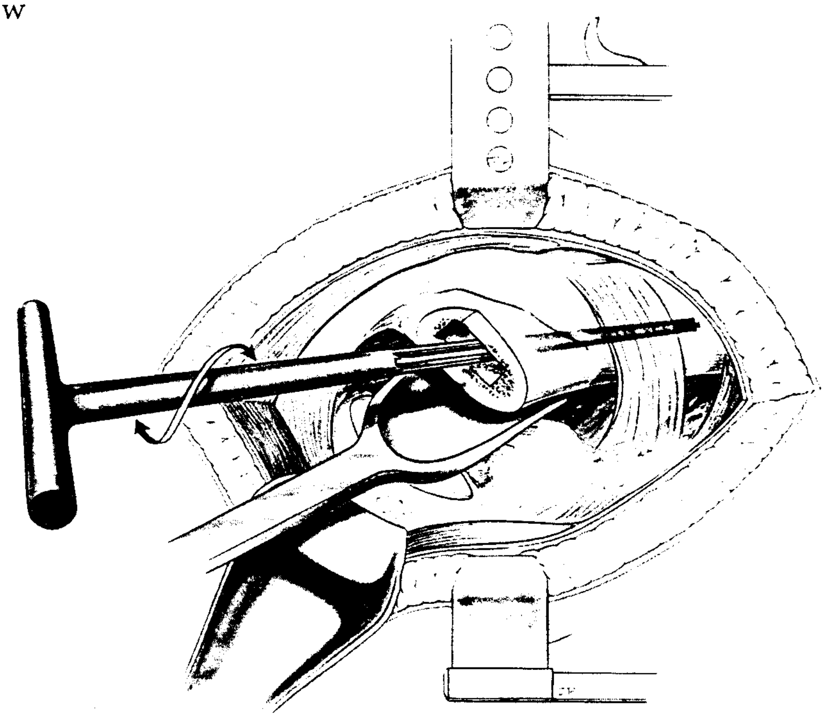


Figure 25: Entry into femoral canal with T-handled tapered reamer

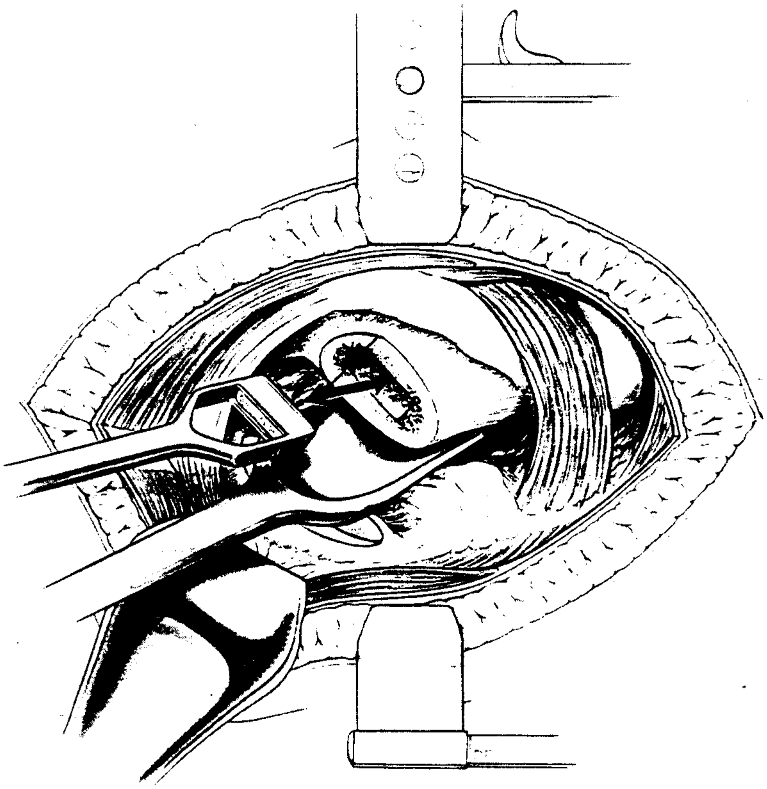


Figure 24: Lateralization of entry point into femoral canal

Femoral Broaching

Broaching is always begun with the #1 broach. The broach is placed on the broach handle and the handle tightened. The broach handle provides for rapid attachment to the broach with rigid fixation and provides striking surfaces for both insertion and removal of the broach (Fig. 26).

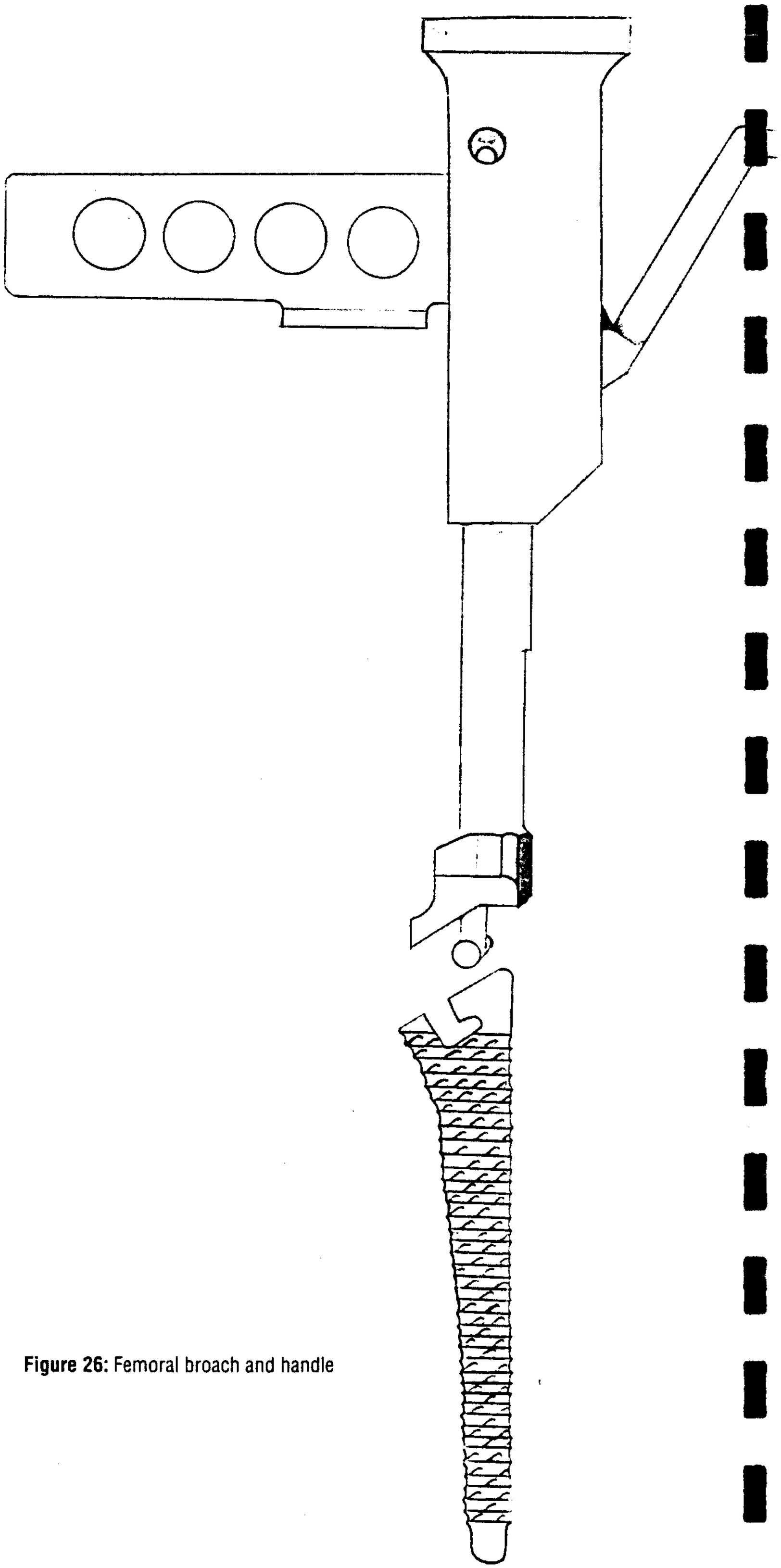


Figure 26: Femoral broach and handle

The broach is inserted in a few degrees of anteversion. This usually corresponds with the anteversion of the patient's femoral neck (Fig. 27). It is wise to remove the broach as it tightens and then advance it again, rather than impacting it fully without withdrawal. This is especially important as the final broach size is approached. Also, with the final broach, it is helpful to rasp laterally with the broach to achieve maximum proximal fill of the femur with the stem and to be sure the stem will be placed in neutral position.

Broaching is done with progressive broach sizes until the maximum size broach is fully seated. Preoperative templating is only a guide. The final decision about prosthesis size is always made during surgery. If substantial resistance is met in inserting a broach smaller than the size selected preoperatively, the surgeon should not risk cortical fracture, but should select a smaller size femoral stem. If this is the case, it may be necessary to adjust the femoral neck length.

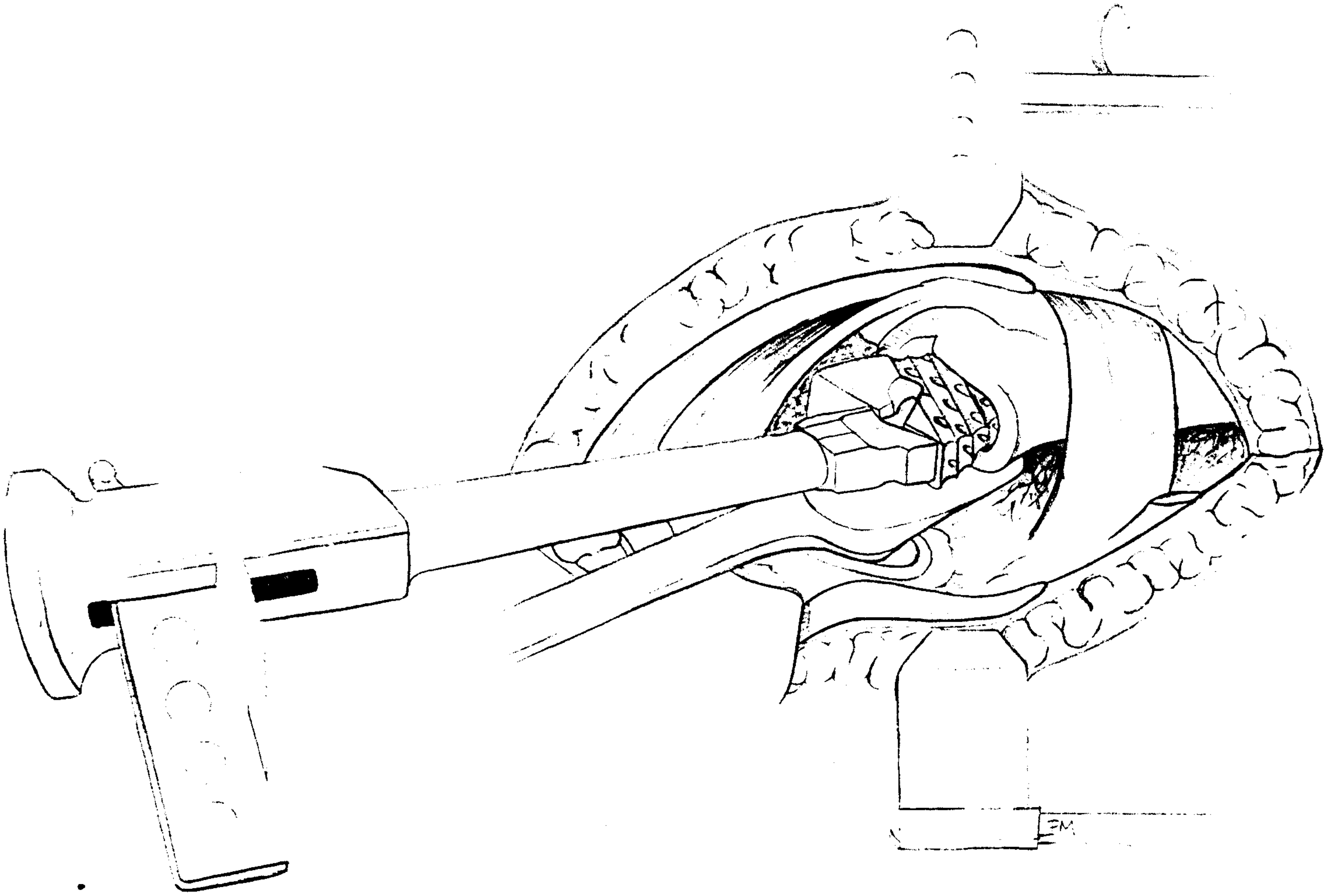


Figure 27: Insertion of femoral broach

Assessing Neck Length

For example, if preoperative templating suggests that a #4 femoral stem is appropriate and at the time of surgery the surgeon selects a #3 stem, the femoral neck of the #3 stem is 5mm shorter than that of the #4 stem. Therefore, if the standard (0) femoral neck length was selected during preoperative templating, changing from the #4 to the #3 stem will require using the long (+5) neck femoral head to achieve the appropriate length.

Reaming

Broaching (without reaming) provides a much more accurate fit and more uniform bone contact of the prosthesis than does reaming. Broaching without reaming avoids the destruction of the blood supply and burning of bone produced by reaming. In unusual cases where the diaphyseal femoral cortex is very thick, creating a narrow canal in relation to the proximal femur, intramedullary reaming may be necessary; this should be in only a small percentage of cases (Table 5). Even though reaming is undesirable because it will destroy the internal blood supply and make the canal into a non-physiologic round shape, the MCS stem will still provide excellent rotational stability (though it will be reduced somewhat compared to non-reamed installation). The MCS stem allows for reestablishment of the internal blood supply so that the femur can respond to stress more physiologically. So even in these circumstances, the MCS stem, because of its design, provides greater rotational stability and more physiologic reconstruction than other stems.

Stem Size		1	2	3	4	5	6	7	8	9	10
Reaming Depth	mm	130	135	140	145	150	155	160	165	170	175
Flexible Reamer Diameter	mm	9.5	11	12	13	14	15	16	17	19	21

Reaming is necessary in only a small number of cases with very narrow femoral canals. The femur is normally prepared with broaching only.

Table 5: Reaming diameter in rare instance when intramedullary reaming is necessary

Trial Reduction

When the appropriate size broach is in place, either the oscillating saw or the femoral neck planer may be used to make final adjustments for optimal fit of the collar against the medial femoral neck cortex (Fig. 28). The femoral neck trial and femoral head trial should be placed and the hip reduced (Fig. 29).

Limb length can be assessed by evaluating the relationship of the level of the tip of the greater trochanter to the center of rotation of the femoral head. If preferred, the surgeon may use other methods of assuring appropriate length. The hip should be placed through a range of motion to assure that stability has been achieved. The hip is then dislocated and trial components are removed.

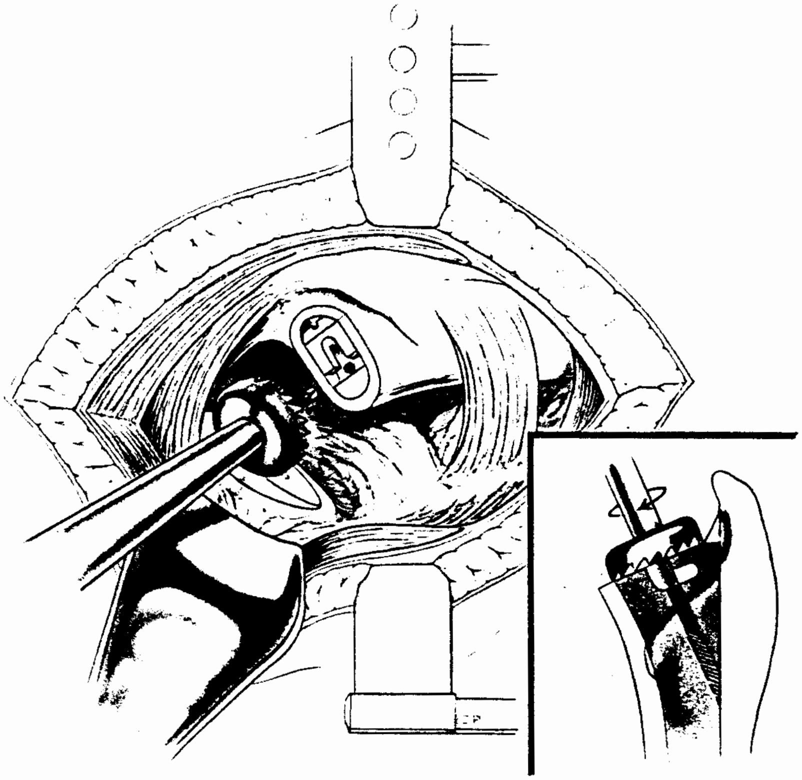


Figure 28: Preparation of the medial femoral neck cortex

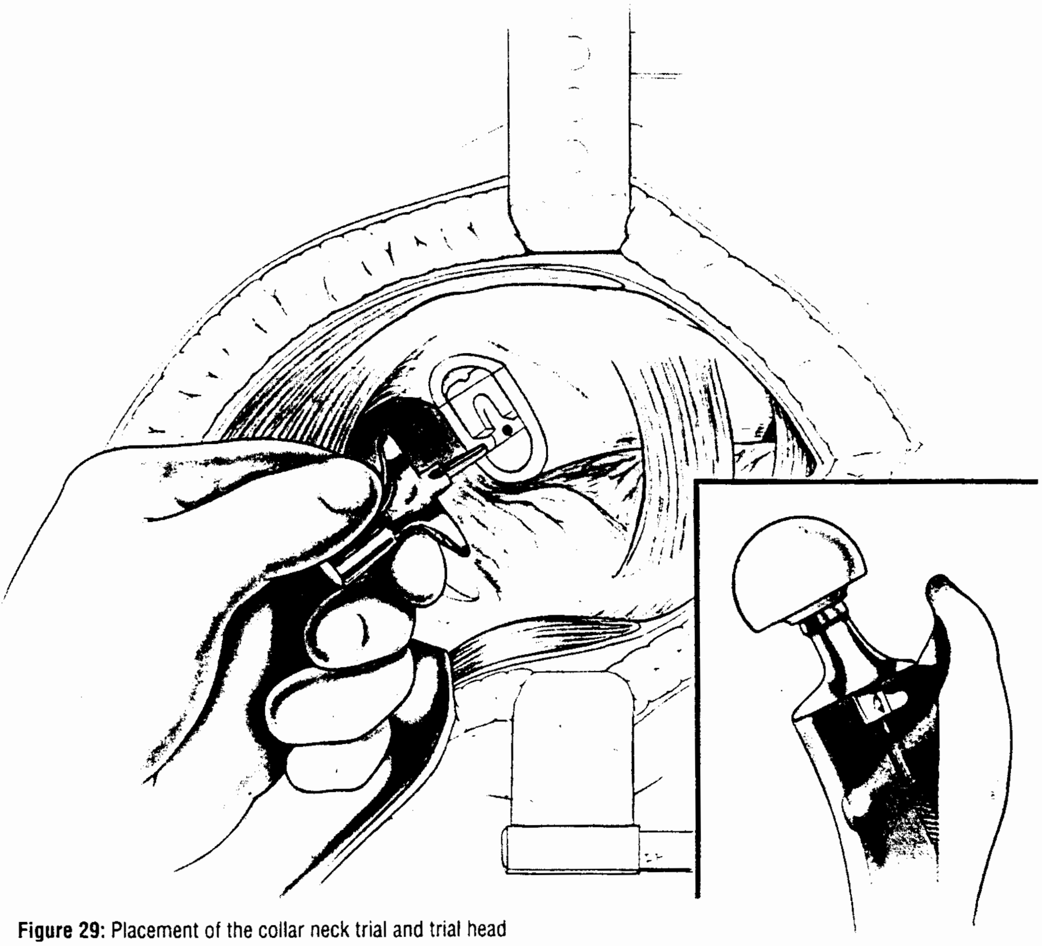


Figure 29: Placement of the collar neck trial and trial head

Stem Placement

The selected stem is placed in the femoral canal by hand following the precision track established by broaching (Fig. 30). Final seating is accomplished by placing the femoral stem impactor in the small lateral receptacle of the stem and tapping the stem into place.

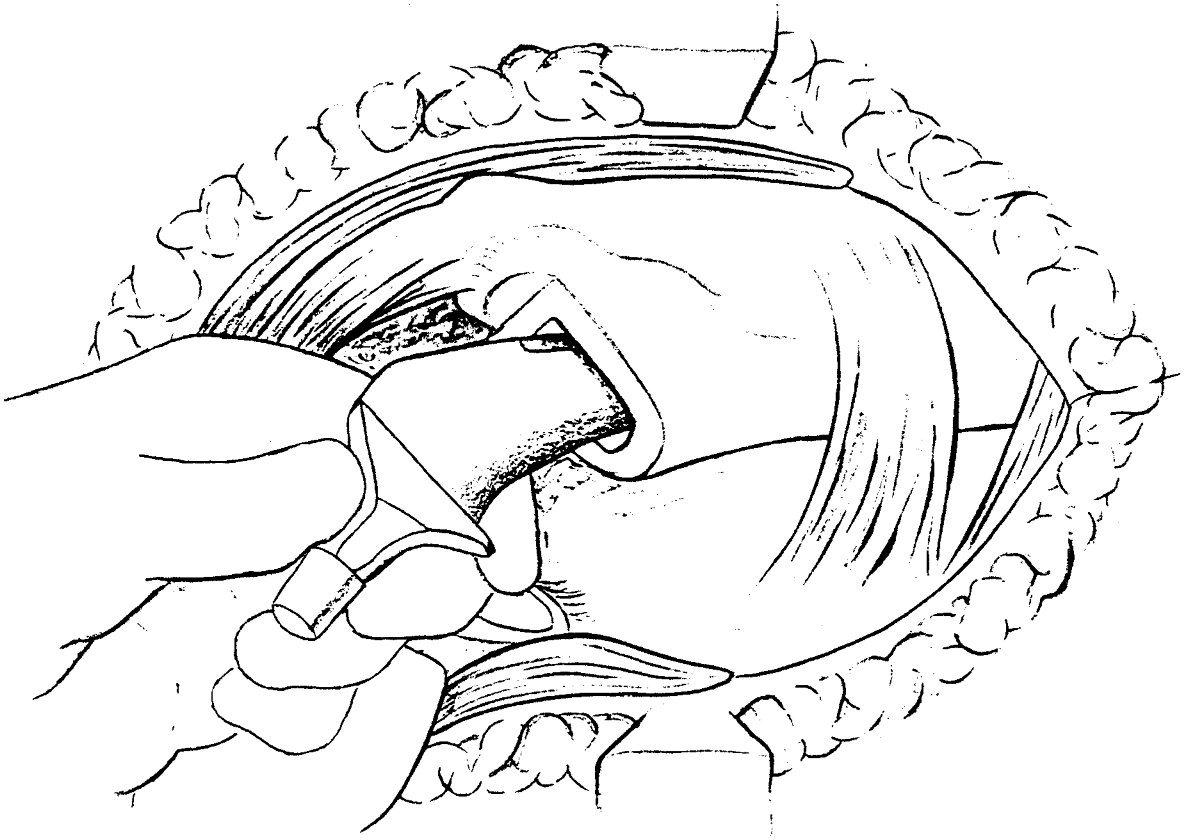


Figure 30: Femoral stem insertion

Final Reduction

If the surgeon desires, he may place the trial femoral head component on the femoral neck taper and carry out another trial reduction to examine length and stability. The tapered femoral neck is cleaned and dried. The selected femoral head component is placed and, using the femoral head impactor, struck with two or three moderate blows (Fig. 31).

The wound is thoroughly irrigated and all debris removed, paying particular attention to the acetabular component. The hip is then gently reduced and length, motion, and stability are checked again (Fig. 32). Closure is performed by the method the surgeon prefers.

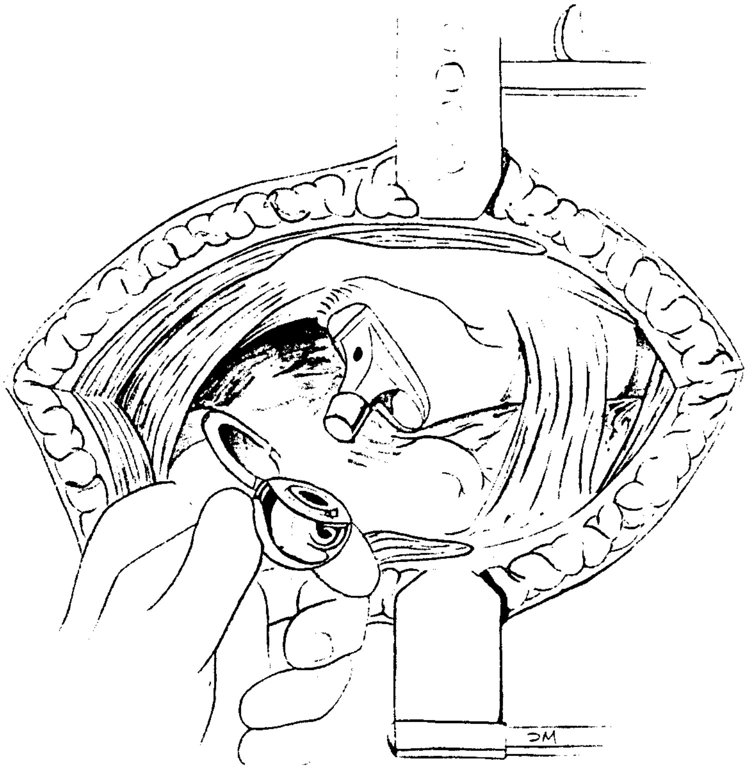


Figure 31: Femoral head placement

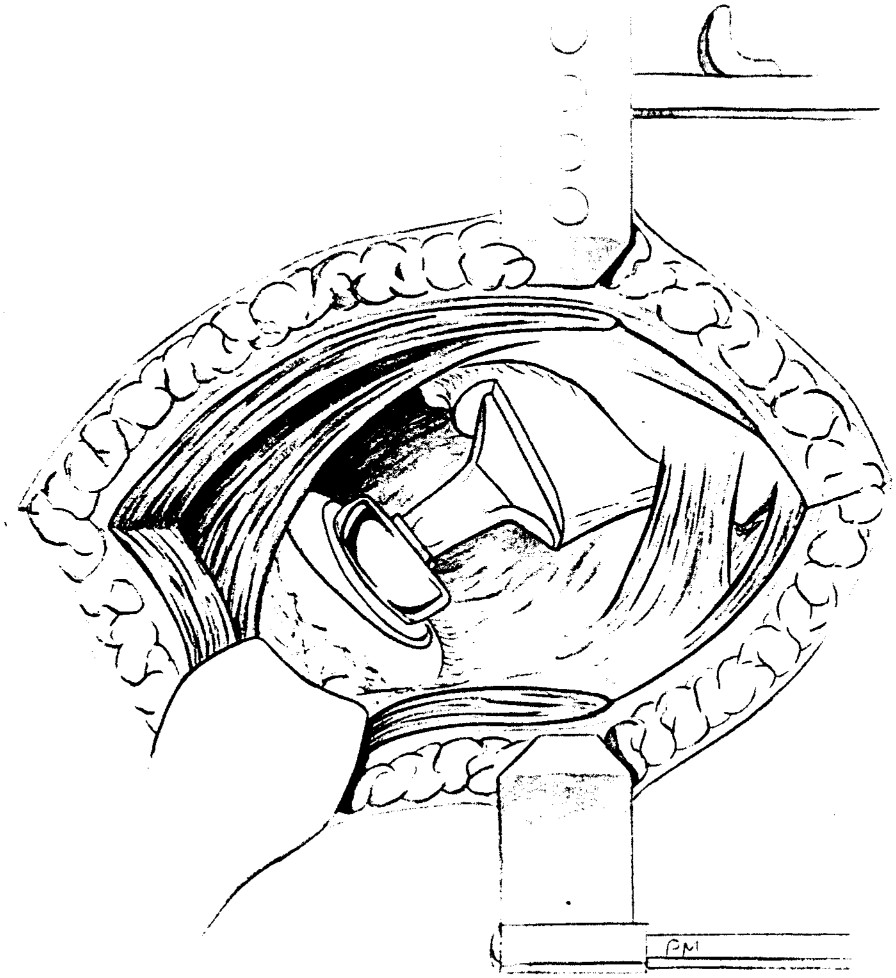


Figure 32: Final reduction

References

1. Keating, E.M.; Ritter, M.A.; Faris, P.M.;
Czarkowski, R.A.; and Brugo, G.:
"An Anatomic Study of Structures at Risk with
Acetabular Screw Fixation of
Total Hip Replacement."
Orthop. Transactions 13: 497,1989.

2. Wasielewski, R.C.; Cooperstein, L.A.; Kruger,
M.P.; and Rubash, H.E.:
"Acetabular Anatomy and Transacetabular Screw
Fixation in Total Hip Arthroplasty."
J. Bone Joint Surg. 72A: 501,1990.

Warning:
Porous coated devices have not been approved
for cementless use in the USA.

3. Broaching is initiated with the smallest **broach** and is continued sequentially to the appropriate size. (**rigid reamers** are available and may be used for distal and mid-stem preparation if desired.)

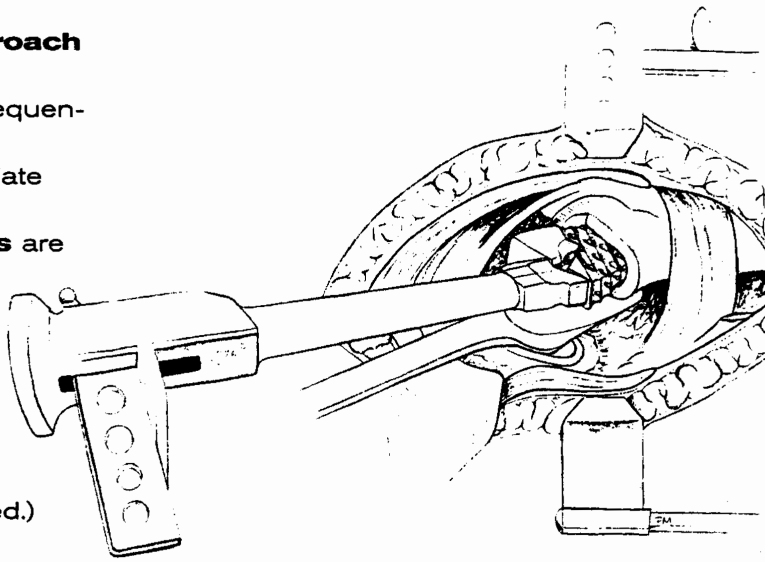


Fig. 3 Insertion of the femoral broach.

4. The osteotomized femoral neck may be adjusted using either an oscillating saw or the **femoral neck planer** to ensure optimal fit of the collar.

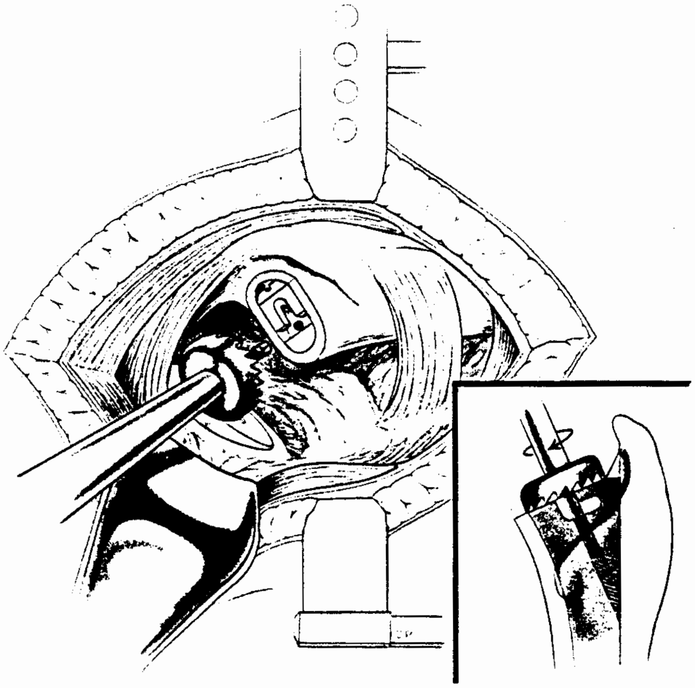


Fig. 4 Preparation of the medial femoral neck cortex.

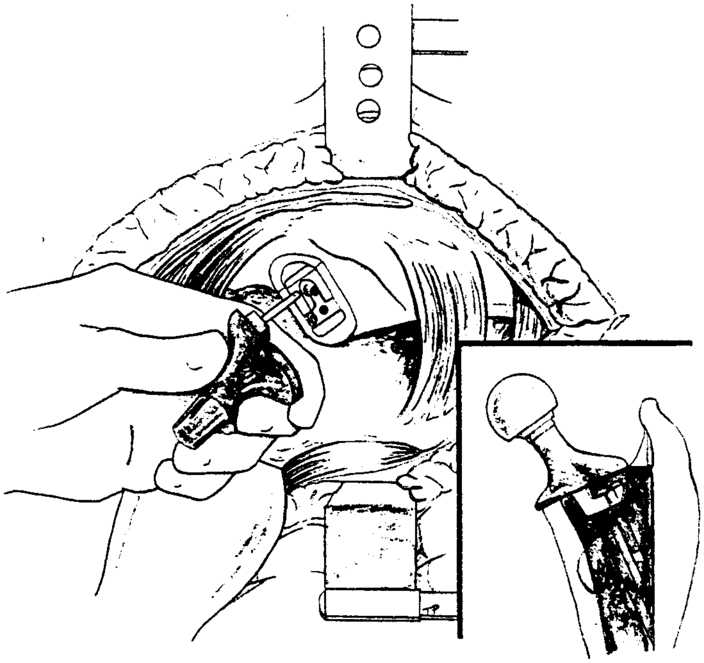


Fig. 5 Placement of collar neck trial and trial head.

5. The fully seated broach serves as a trial for press-fit application, and as a trial incorporating the cement mantle for cemented use. The appropriate **collar neck trial** and **femoral head trial** are placed for trial reduction.

6. A **centralizer sizer** is available to establish the appropriate centralizer diameter. If reaming was performed, final reamer diameter may be used in lieu of the sizer.

6a. In cemented use, the stem centralizer is pressed by hand into the distal stem. The stem is inserted into the cement in the femoral canal after the cement has been introduced.

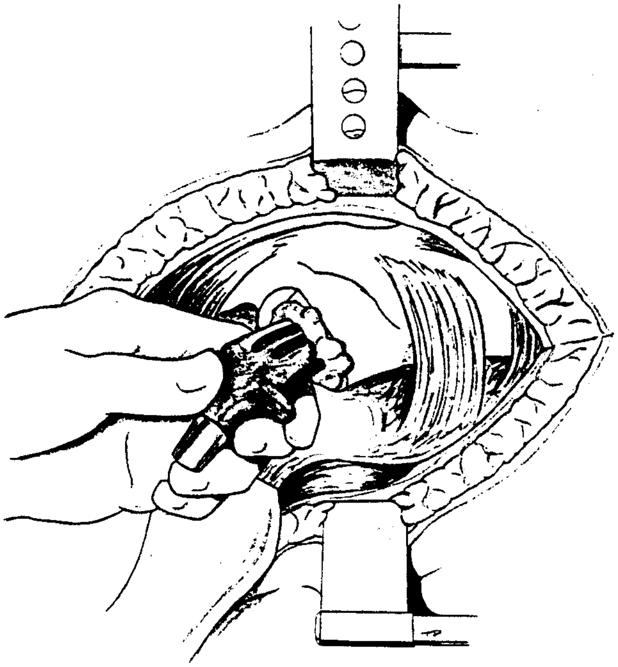


Fig. 6a Placement of stem (with cement).

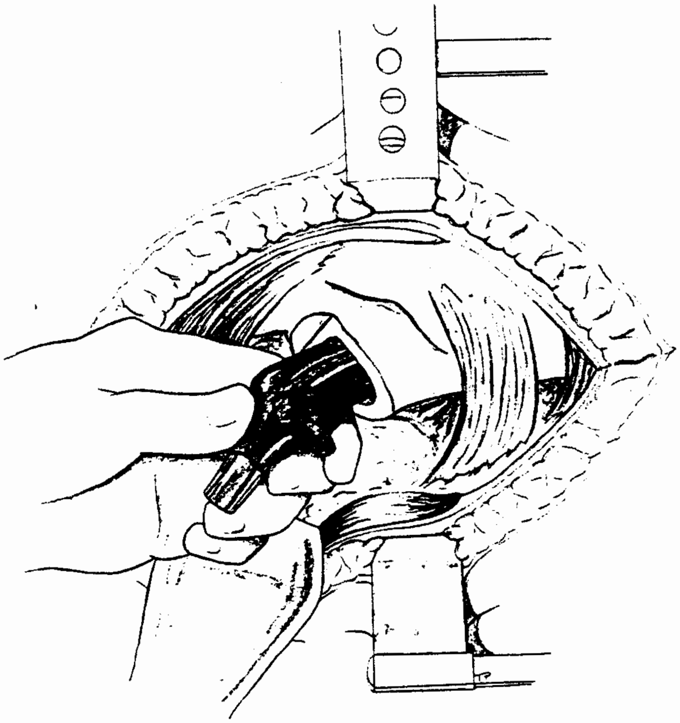


Fig. 6b Press-fit insertion of femoral stem.

[illegible] tract established by broaching (note: the proper implant size for press-fit use is one size larger than the broach used. For example: if a size 3 broach is used, a size 4 implant will properly press-fit.

For both cemented and press-fit use, a **femoral stem impactor** is used to seat the femoral stem into final position.

7. The selected femoral head is placed on the cleaned, dried taper of the femoral neck and the wound is closed.

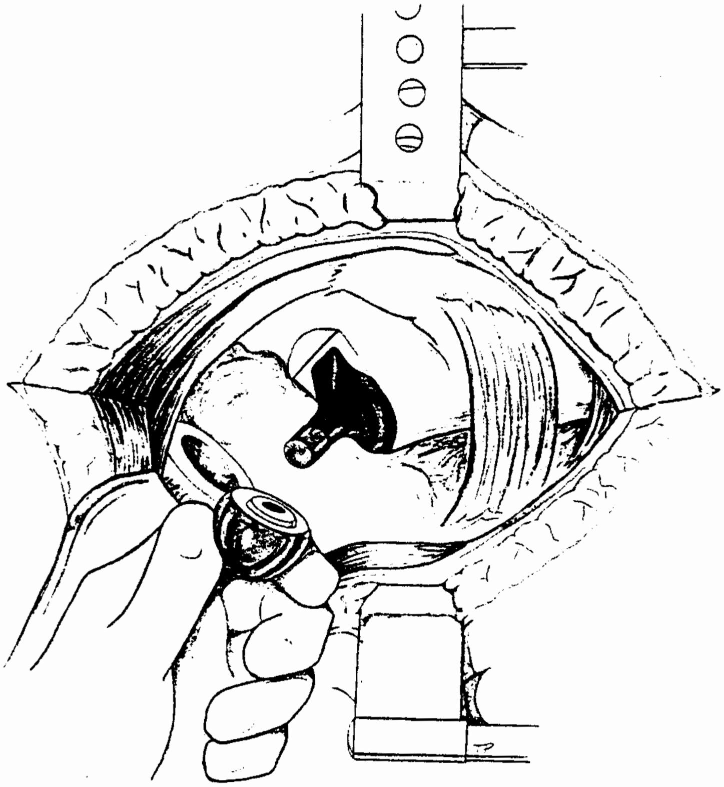


Fig. 7 Femoral head placement.

Opteon Size and Neck Length Table

Stem Size	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The Opteon® Femoral Stem is designed and manufactured to the uncompromised standards that all patients deserve. The material is forged cobalt chromium alloy. The stem is available in five sizes that have been designed based on anthropometric studies of the human femur.

The surgeon may elect intraoperatively to cement or press-fit. The Opteon® stem uses the same tray of simple femoral instruments common to all other Exactech® femoral stems. Special Opteon® broaches further increase the efficiency of the procedure.

OPTEON®

OPTEON® FEMORAL STEM BY EXACTECH®

OPTEON® FEMORAL STEM BY EXACTECH® Surgical Technique was developed in consultation with the Orthopaedic Surgery Staff of Morton Plant Health Systems

EXACTECH®

Gainesville, FL. U.S.A. 32609
1(800) EXACTECH

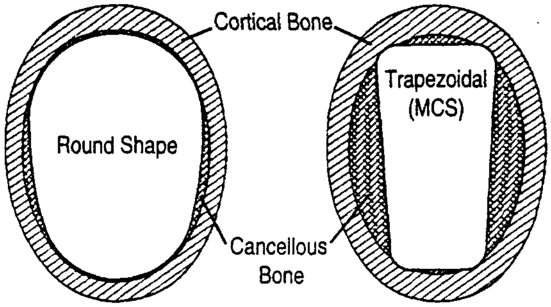
Profile Number 1-FS February 1993

STABILITY AND STRESS TRANSFER OF FEMORAL STEMS OF DIFFERING DESIGNS

Introduction

The goals in the design of a cementless femoral stem for total hip arthroplasty are to provide stability to facilitate bone ingrowth into its porous structure, and to reduce the chance of thigh pain from micromotion or abnormal stress transfer to the femur.

A trapezoidal cross sectional geometry achieves inherent stability in the femoral canal. Material selection and additional cross sectional design features are advantageous in providing more normal stress transfer to the femur.



(Figure1) Cross Section of Round Shape Vs. Trapezoidal (MCS) in the Femoral Canal

Stability

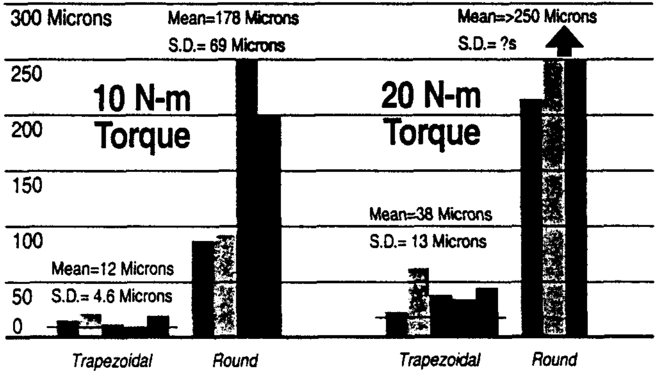
Torsional stability testing using cadaveric bone has been carried out in the laboratory comparing a straight femoral stem with trapezoidal cross section (MCS) to a similarly sized stem with circular cross sectional geometry.

Five femur pairs were prepared using the recommended surgical technique. An MCS femoral stem was implanted on one side and an appropriate sized implant based on circular stem geometry was placed in the contralateral femoral sample.

A special fixture was clamped to the stem neck which allowed attachment of a torque wrench and displacement transducer. The bone was clamped and torsional loads of 10 N-m and 20 N-m were applied while monitoring proximal rotational displacement.

Figure 2 shows the results of the testing. The mean rotational displacement at 10 N-m for the MCS stem was 12 microns (S.D.=4.6 microns) compared to 178 microns (S.D.=69 microns) for the circular stem. At a torque of 20 N-m, the MCS exhibited 38 microns (S.D.=13 microns) of motion compared to greater than 250 microns for the round type stem.

Rotaional Stability- Comparison of Trapezoidal Vs. Round Stems



(Figure 2) Rotational stability - comparison of the MCS femoral component to a collared, straight stem of circular cross section produced by another manufacturer. At both 10 and 20 N-m of torque, the mean torsional displacement of the Exactech MCS stem (12 microns and 38 microns) was significantly lower than the other stem (178 microns and > 250 microns).

Straight vs. Curved Stems

Straight stem designs lead to more stable and reproducible performance (Manley, et al) with 44% less translational and 62% less rotational motion (Noble, et al)

Noble, et al has shown that "an average of 44% less translational micromotion and 62% less rotational motion was observed with straight stems compared with anatomic components." This finding is supported by Manley, et al who also found curved stem geometry to be relatively unstable and unpredictable in performance.

Stress Transfer

Distal Stem Design

Distal stem end configuration affects the stresses in bone. Endosteal bending stresses can be reduced by 38% by increasing the stem tip radius (Englehardt). The MCS stem incorporates this concept into distal stem geometries.

Stem Stiffness

Stem stiffness also affects distal bone stresses. A stiffer stem is more likely to produce proximal stress shielding and stress concentration at the tip of the stem. This suggests it is desirable for femoral stem stiffness to approximate the stiffness of the femoral bone. Three approaches have been used to reduce the stiffness of a femoral stem: 1) hollowing the stem out, making it a tube; 2) placing a coronal split in the stem; ("clothespin"); and 3) removing material by placing longitudinal channels in the distal stem.

Hollowing the stem out is not very effective in reducing stiffness.(Figure 3) So much material is removed that the stem becomes weak. This is because removing material from inside the stem leaves a high area moment of inertia, thus reducing stiffness very little, even when substantial material is removed.

A Coronal split in a stem can reduce stem stiffness by up to ninety-five per cent. Perhaps this is more stiffness reduction than is desired. Even more important, the reduction in stiffness produced by the split is in one plane only, so there is little or no reduction in stiffness in the plane at right angles to the split.

Channels of increasing depth and width on all sides of the distal stem produce substantial reduction in stem stiffness with negligible effect on the strength of the stem. (Figure 4) Computer analysis allows such channels to be designed for maximum effect on a given stem size. The channels have the additional effect of reducing stiffness in all planes of the stem.

Conclusions

Stability and stress transfer are key elements in the interaction between bone and a cementless femoral stem for total hip arthroplasty. A straight stem provides greater axial stability than a curved stem. The more a stem departs from a round shape, the greater its rotational stability. More normal transfer of stress from stem to bone can be achieved by more closely matching stem stiffness to that of bone and by preventing abrupt stress changes at the tip of a blunt stem. The likely clinical corollary of these improved design features is less thigh pain and less abnormal bone remodeling.

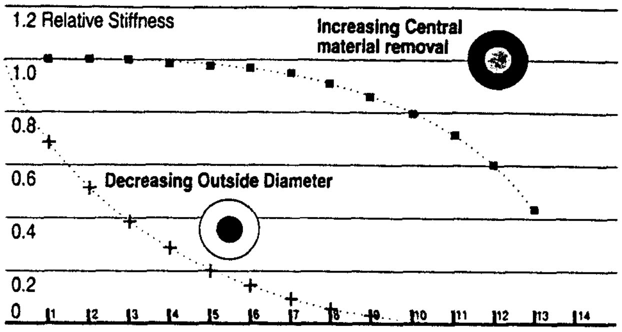


Figure 3 Stiffness Comparison
Effect of Cross-Section Material Removal

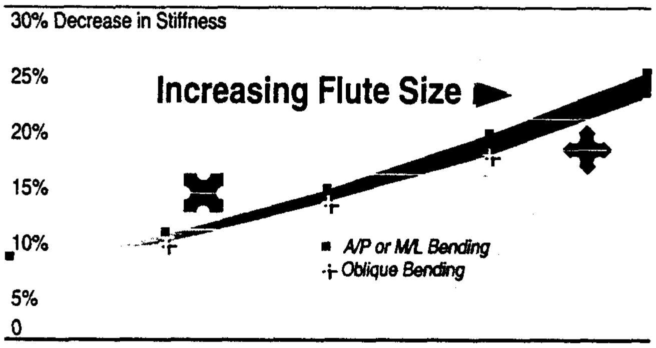


Figure 4 Stiffness Comparison
Effect of Increased Flute Size

References

Noble, P.C., Kamaric, E., Alexander, J.W., and Tullos;
"The Effect of Stem Shape On Mechanical Stability of a Cementless Femoral Component". Proceedings of the 16th Annual Meeting of the Society for Biomaterials, 1990, p. 56.

Manley, M.T., Cohen, R.C., Averill, R.G., and Capello,W.N.;
"Torsional Stability Between Femoral Stems and Bone". Proceedings of the 16th Annual Meeting of the Society for Biomaterials, 1990, p. 219.

Englehardt, J.A., and Tomaszewski, P.R.;
"Hip Stem Fixation and Tip Geometry: A Theoretical Model for Thigh Pain". Proceedings of the 37th Annual Meeting of the O.R.S., 1991, p. 270.

Technical Data Sheet Sponsored by

EXACTECH®
Gainesville, Florida 32609
(904) 377-1140

Profile Number 1-FH February 1993

REDUCTION OF FRICTION AND WEAR AT THE INTERFACE BETWEEN THE FEMORAL HEAD AND THE ACETABULAR COMPONENT

Introduction

Reduction of friction and wear at the interface between the femoral head component and the acetabular component has been an important issue in the evolution of the "Low Friction Arthroplasty" of Sir John Charnley. Efforts to reduce wear and friction between the components have culminated with the acceptance of Yttria stabilized Zirconia, an advanced ceramic, as material superior to CoCr for use as a bearing surface in modular femoral heads for THA.

Mechanical Properties

Surface Finish

Use of Zirconia in a femoral head component can reduce polyethylene wear for several reasons which are a direct result of the mechanical properties of Zirconia. Because of the small, tetragonal grain structure of Zirconia, high bearing ratio surfaces can be generated at < 1 micro inch Cla values.

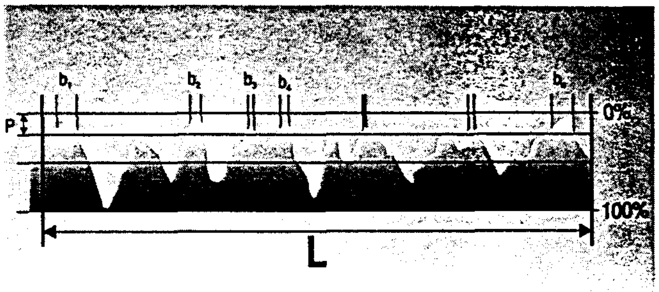
The superior bearing surface of Zirconia compared to metals is further enhanced by its resistance to scratching because of its higher hardness. Furthermore, should the bearing surface become scratched, Zirconia is less offensive to polyethylene than metal due to its scratch profile.

Wear Rate Comparisons

The surface finish advantages of Zirconia compared to CoCr translate directly to a clinical advantage in significantly reducing the polyethylene wear rate. It has been reported that certain metals can yield better wear rates than Zirconia, but is important to note that wear rates are proportional to attained surface finish. It is possible, if desired, to intentionally finish a Zirconia ceramic femoral head only to the same R_a (average roughness) of a metal head. The Zirconia would then yield higher wear rates for one of the same reasons it is a superior material - its- greater hardness. However, when Zirconia and metals are polished to their respective attainable surface finishes, as would be supplied by an orthopaedic company for implantation, Zirconia clearly out- performs both metal and other ceramic materials. (See Wear Rate Comparison chart reverse side)

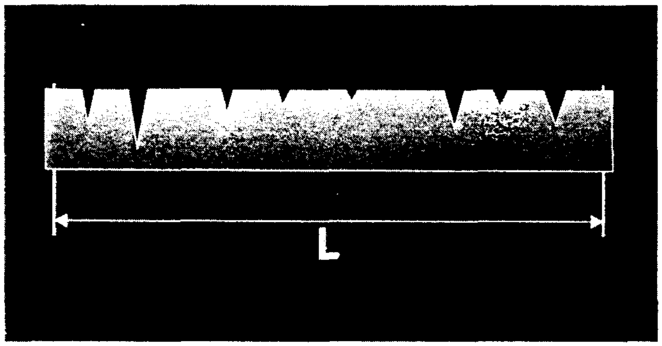
Bearing Ratio tp

Profile of Typical Metal Surface (Figure1)



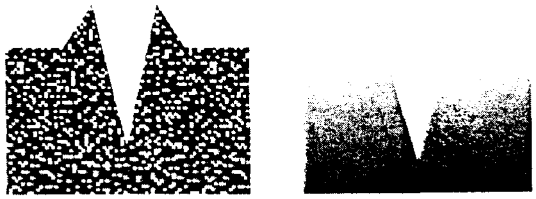
Bearing ratio tp is the length of bearing surface (expressed as a percentage of the assesment length L), at a depth p below the highest peak. tp (%) is the ratio of the depth p.

Profile of Typical Ceramic Surface (Figure 1 Cont.)



$$\frac{t_p = b_1 + b_2 + b_3 + b_4 .... b_n}{L} \ X\ 100 = \frac{100}{L} \sum_{1=1}^{1=n} b1$$

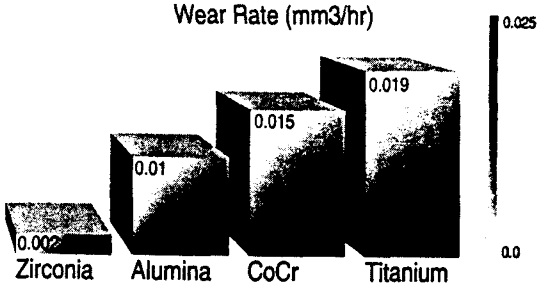
Typical scratch profile of metal and ceramic counterfaces (Figure 2)



Metal

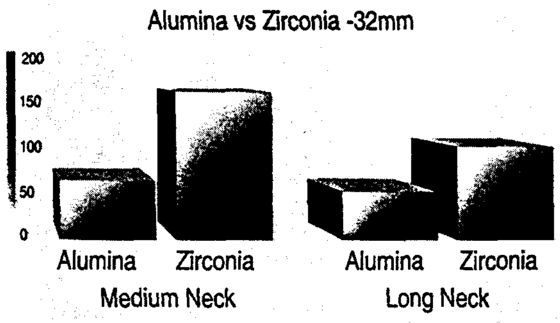
Ceramic

Wear Rate Comparisons (Figure 3)



Wear Rates of Common Materials Articulating with UHMWPE

Breaking Strength Comparisons (Figure 4)



Breaking Strengths of Alumina and Zirconia Femoral Heads

Mechanical Strength

The high fracture toughness of Zirconia makes it a safe choice for use in THA modular femoral heads. Zirconia has a bending strength 2 to 2.4 times that of Alumina, its predecessor in ceramic use for THA.

Fracture toughness is the ability of a material to resist cracking. Zirconia's superior fracture toughness is the result of its ability to undergo a specific stress induced transformation. Upon initiation of a crack, the grains contiguous to the crack transform from a tetragonal phase to a monoclinic phase. Adjacent untransformed grains restrict expansion of the transformed material and the crack closes rather than propagating. Relative to fracture toughness, Zirconia offers an advantage traditionally associated with metals.

Biocompatibility

With Zirconia, there is no evidence of adverse tissue reaction (Ref). In fact, studies show that biologic responses to Zirconia are similar to those of its accepted predecessor, Alumina (Ref).

Conclusions

A fine grain structure, allowing Zirconia to be polished to a surface finish typically highly superior to that attainable in metals, combined with higher hardness characteristics and an advantageous scratch profile make Zirconia capable of producing extremely low polyethylene wear rates. Also, in addition to its biocompatibility, the pre-stressed tetragonal grain structure of Zirconia provides for a very high fracture toughness to make it safe for use in modular femoral heads for THA.

References

Figure 1 and Figure 2 - Courtesy of **Morgan Matroc, Ltd.**

Figure 3 and Figure 4 - **Schwartz, G.L.**, "Wear and Strength of Zirconia and Alumina Ceramic Materials". Trans. ORS, p. 483, 1990.

1. **Garvie, R.C., Urbani, C., Kennedy, D.R., and McNeuer, J.C.**: "Biocompatibility of Masnesra Partially Stabilized Zirconia", **J. Mater**. Sci. 19: 3224-3228, 1984.

2. **Christel, P., Meunier, A., Heller, M.**, et al.: "Mechanical Properties and Short Term in Vivo Evaluation of Yttrium-Oxide partially stabilized Zirconia". J. Biomed. Mater Res 23:45-61, 1989.

Research Advisory Panel

Gary J. Miller, Ph.D.
University of Florida Health Science Center
Derick Cooper
Morgan Matroc, Ltd., Surrey England

Technical Data Sheet Sponsored by:
EXACTECH®
Gainesville, Florida 32609
(904) 377-1140