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Minimally Invasive Hip and Knee Replacement:
Surgical Techniques and Computer Navigation
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Total hip arthroplasty performed using conventional and navigated tissue-preserving techniques

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1. **Introduction**

Conventional total hip arthroplasty (THA) in its many forms has been well established as a reliable procedure with predictable recovery. By contrast, less invasive surgical techniques have been popularized without a strong scientific foundation. Most early reports document an increased incidence of perioperative complications as compared to established standards [1-5]. These complications include increased incidences of femur fracture, cup malposition, dislocation, infection, abductor morbidity, and nerve palsy [6]. Less invasive techniques vary widely with regard to the tissue intervals chosen and these choices largely determine the most common complications encountered.

A new technique of THA was developed with the specific goals of maximally preserving the soft tissues surrounding the hip joint, allowing the exposure to be easily transitioned into a conventional exposure, and protecting the abductor musculature during surgery. The technique involves inserting both the femoral and acetabular components anterior to the posterior capsule and short rotators and posterior to the gluteus medius and minimus[7,8].

This current handout demonstrates the technique of Superior Capsulotomy and reports on a study prospectively comparing recovery and perioperative complications of a consecutive series of THA performed using a transgluteal exposure to a consecutive series of THA performed using a superior capsulotomy.

2. Superior Capsulotomy – Indications, Planning and Technique

Introduction

Tissue-Preserving Total Hip Arthroplasty using a Superior Capsulotomy is a technique that allows for implantation of the total hip components under direction vision through a single incision. The technique allows for recovery that is as rapid as a mini-posterior exposure while conferring stability of the hip joint that is equal to other exposures that preserve the posterior hip joint capsule and short external rotators. Our experience (reported below) demonstrates that the technique is actually safer than total hip arthroplasty performed using a direct lateral exposure and results in very rapid recovery.

The technique is best learned by observing the surgery 1st hand and then performing the surgery on cadaveric specimens. Surgeons who perform the miniposterior exposure can transition to the superior capsulotomy technique gradually over a number of total hip procedures. Assisting in surgery is also possible and encouraged, but requires obtaining a temporary medical license and temporary hospital privileges, which is a process that can take 3 or more months. Additional information, including copies of manuscripts, may be downloaded at stephenmurphy.org.

Indications

This technique is indicated for any standard total hip arthroplasty where there is no preexisting hardware, where there is typical amount of space between the acetabular rim and the greater trochanter, and where there is an absence of significant malformation of the hip. Heavy patients can be efficiently treated with the technique. In fact, the difference in difficulty between thin and obese patients is actually less than it is with the miniposterior or direct lateral exposures although initially experience should focus on simpler total hip arthroplasties before the technique is applied to obese patients or patients with prior surgery or more significant deformities.

Preoperative Planning.

Preoperative planning should be performed as usual, with the exception that the placement of the femoral component should be measured in relation to the tip of the greater trochanter rather than in relation to the lesser trochanter.

Patient Positioning

The patient is positioned in the lateral position with the body positioned a little bit toward the anterior side of the table, so that the hip can be maximally adducted (Figure 1).

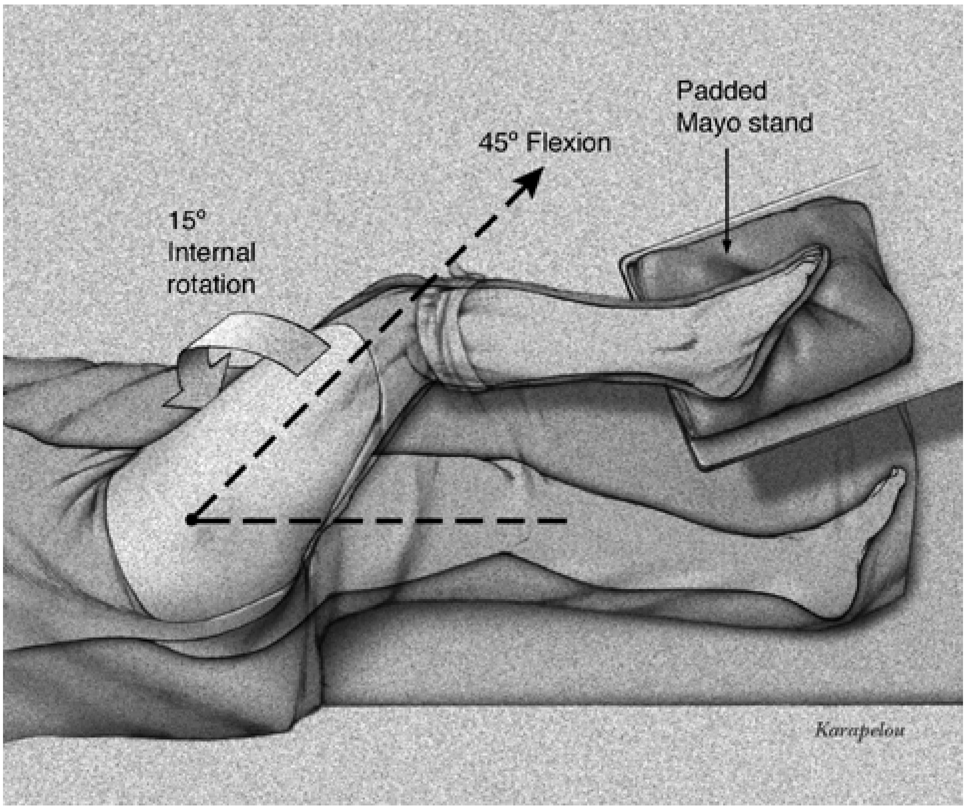

Figure 1.

Incision placement

With the hip flexed 45 degrees, the incision is placed starting at the tip of the greater trochanter and extending 8cm proximally, exactly in line with the femoral shaft axis (Figure 2).

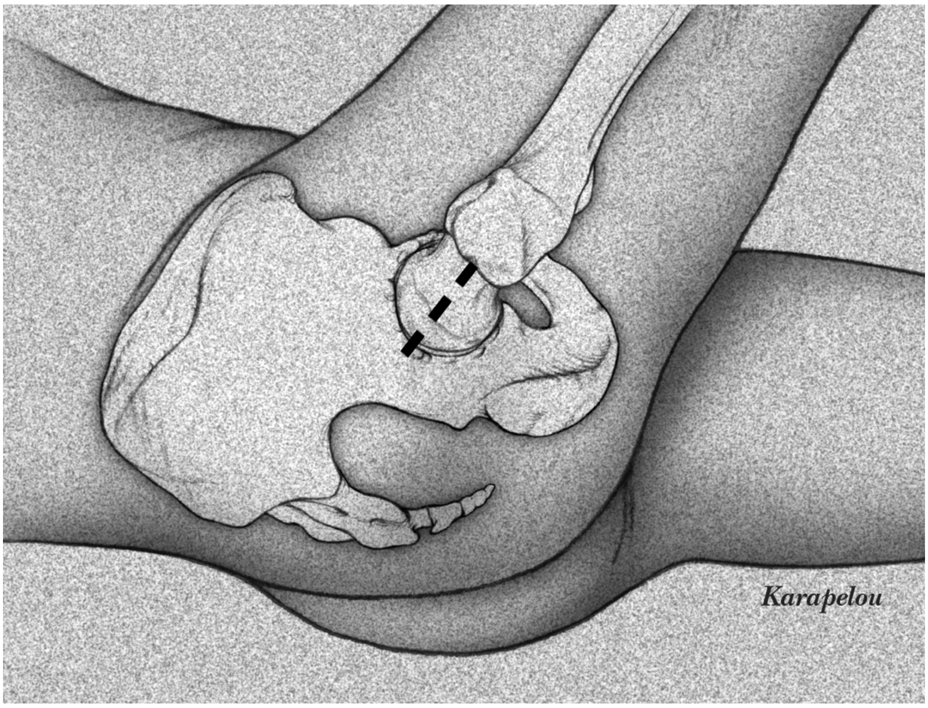

Figure 2.

Technique of the Exposure

The incision is made to the level of the fascia. The fascia is incised, starting at the tip of the greater trochanter, and extending again in line with the incision. Two wing-tipped elevators are then used to spread the gluteus maximus fibers to expose the bursa tissue overlying the gluteus medius muscle. The very thin later of bursa tissue is then carefully incised just along the posterior border of the gluteus medius.

A blunt pull retractor is then placed on the posterior border of the gluteus medius to expose the piriformis tendon and gluteus minimus muscle (Figure 3).

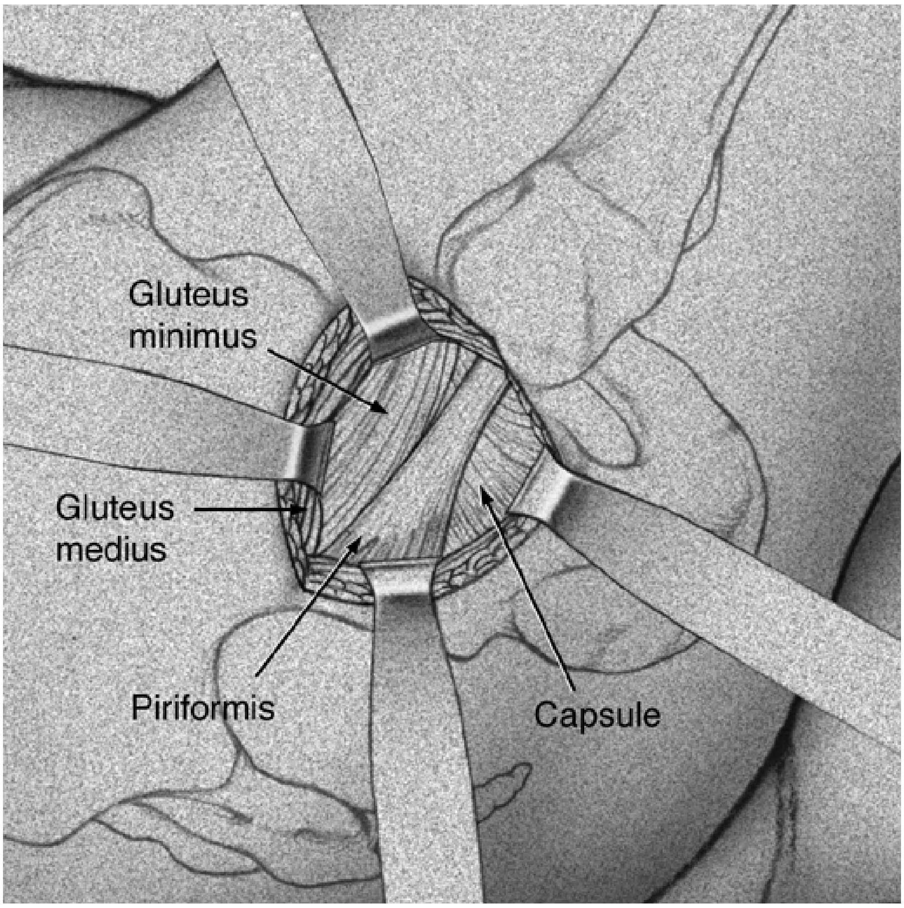

Figure 3.

A Cobb elevator is placed underneath the anterior aspect of the piriformis tendon at its insertion on the piriformis fossa. A blunt pull retractor is the placed on the piriformis tendon and pulled inferiorly to move the posterior border of the gluteus medius out of the way, to maximally expose the piriformis tendon as distally as possible. A long-handled knife is then used to transect the piriformis tendon as distal as possible. Take care not to extend the cut into the superior gemellis or obturator internus tendon.

Identify the posterior border of the gluteus minimus and mobilize the muscle from the hip joint capsule from posterior to anterior using a cob elevator (Figure 4).

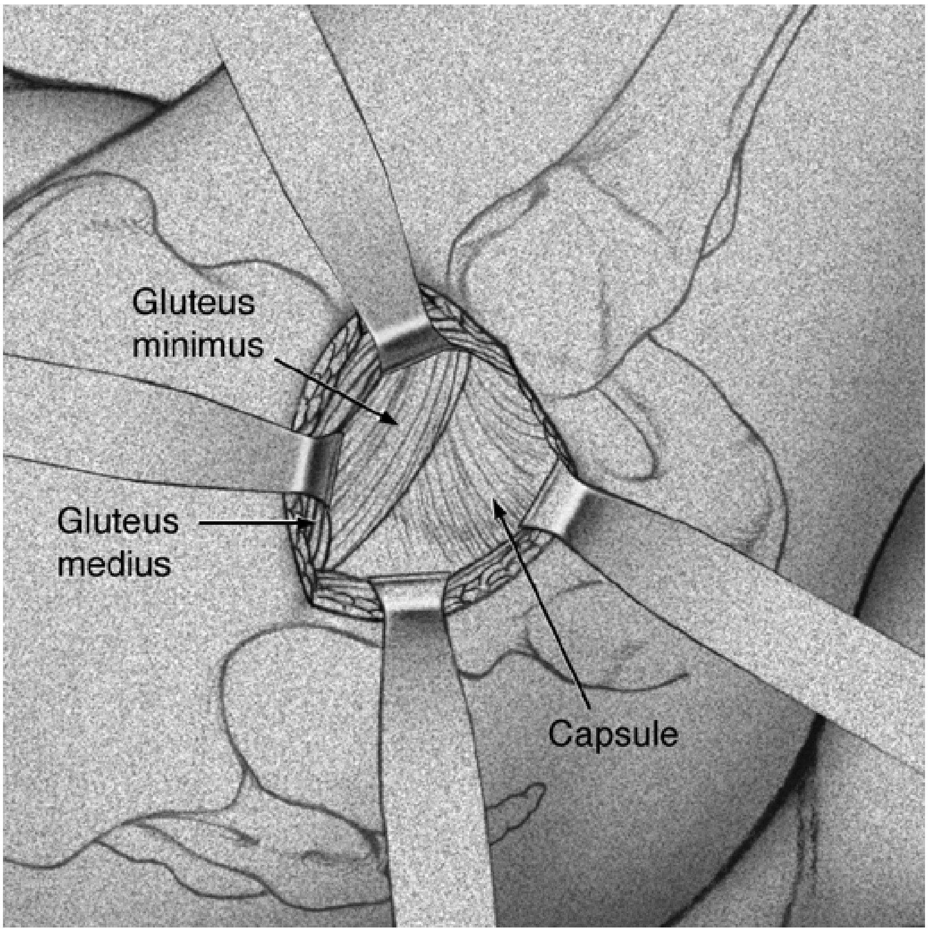

Figure 4.

Sharp dissection with a knife may be necessary at the start. Use the Cobb elevator to develop the interval between the minimus tendon and the anterior hip joint capsule. Place a blunt Homan elevator around the anterior hip joint capsule and place a spiked Homan retractor into the anterior ilium, just past the anterior/superior acetabular rim and underneath the gluteus minimus.

Make an incision in the superior hip joint capsule from 6 O’clock in the trochanteric fossa to a little posterior of 12 O’clock at the superior acetabular rim. Use a long electrocautery to incise in the trochanteric fossa to prevent bleeding of the anastamosis around the base of the femoral neck. Make another incision in the anterior superior capsule for about 20mm along the acetabular rim. Place a tagging suture at the corner of the capsule (figure 5).

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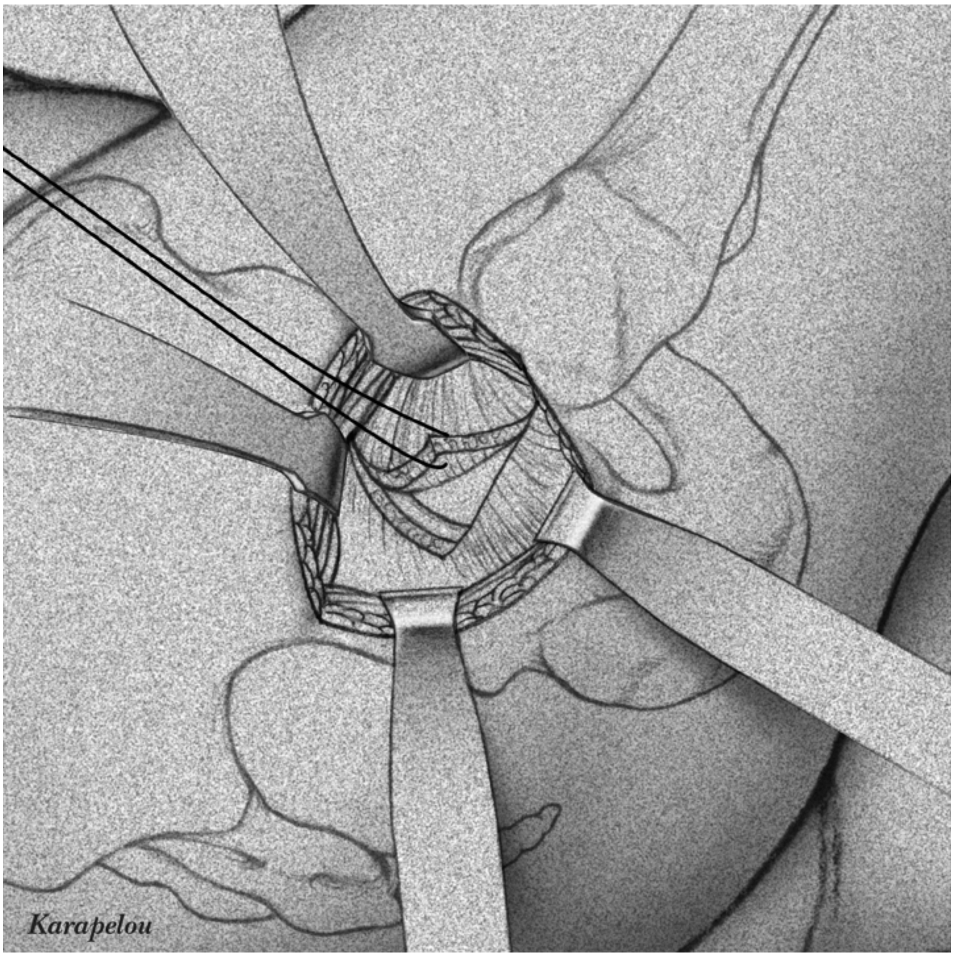


Figure 5.

Make a third incision in the anterior hip capsule underneath the tendon of the gluteus minimus, along the anterior neck, into the trochanteric fossa to create a U-shaped anterior capsular flap, Leave the spiked Homan in the anterior ilium. Place two blunt Homan retractors inside the hip joint capsule around the anterior and posterior femoral neck.

Place another spiked Homan in the posterior/superior portion of the femoral head to complete the retraction (figure 6).

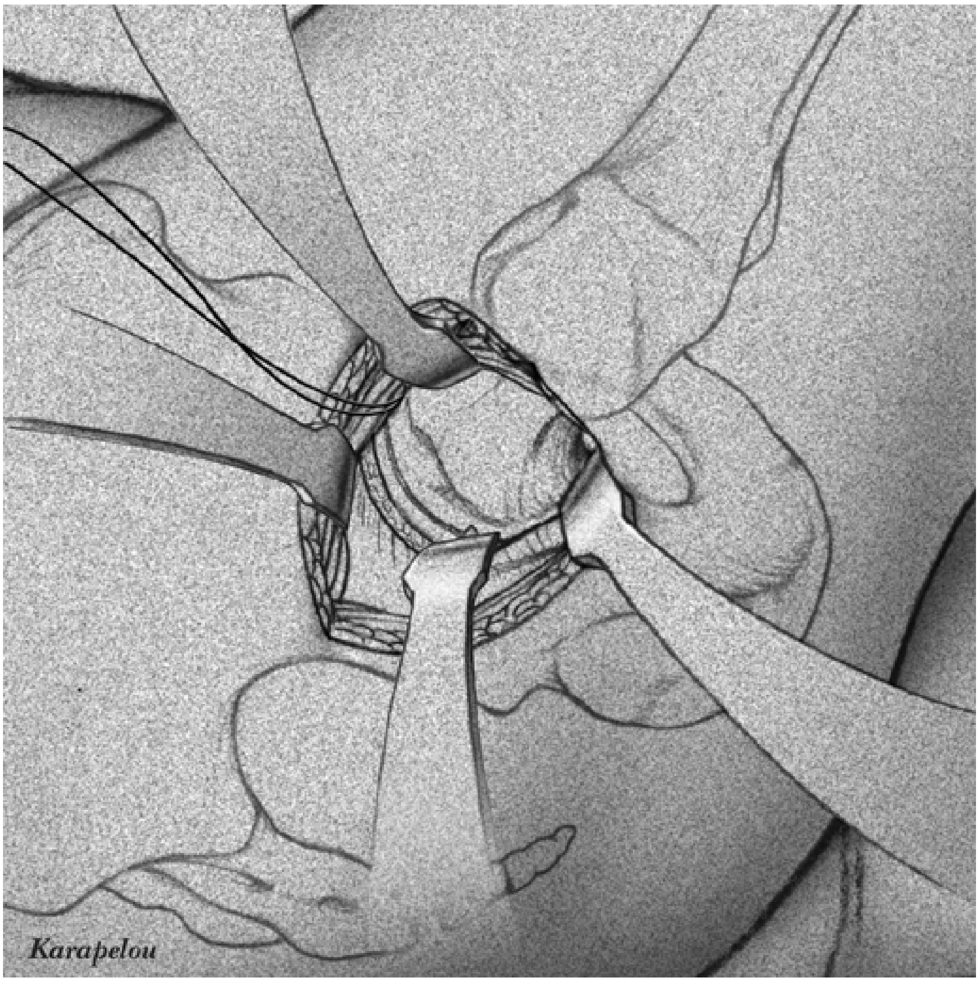


Figure 6.

Preparing the femur

Using an end-cutting cylindrical starting reamer, enter the femoral canal through the trochanteric fossa (Figure 7).

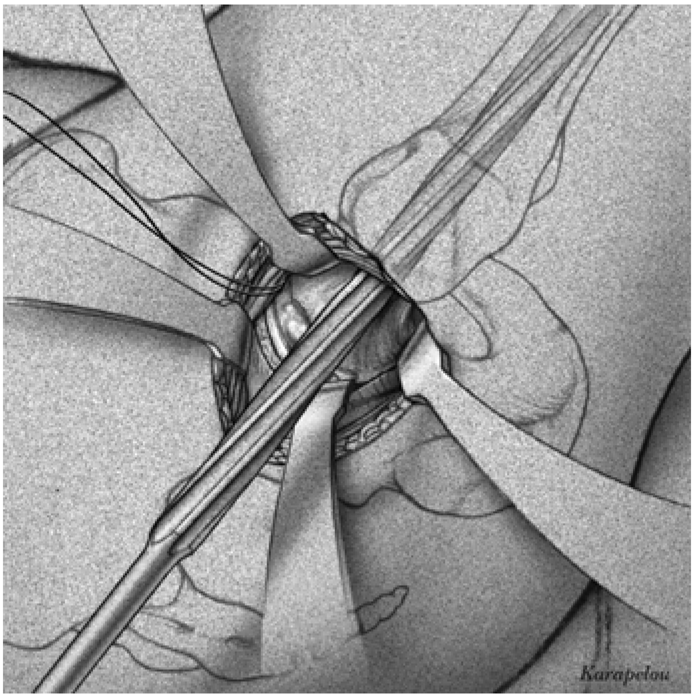


Figure 7.

Use a conical metaphyseal reamer to expand the proximal opening, ensuring that the subsequent instruments are in proper alignment and not in varus (Figure 8).

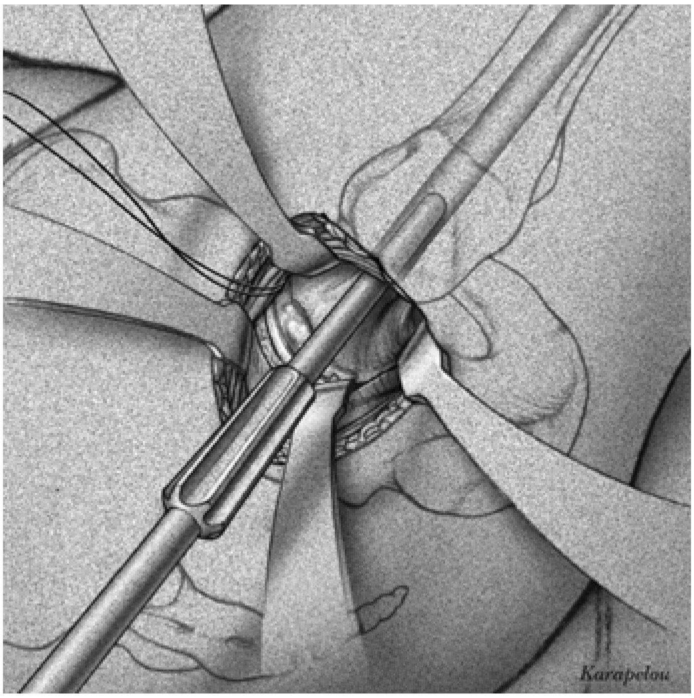


Figure 8.

Use cylindrical reamers up to proper size if the femoral component requires them. Use an osteotome to open superior neck and lateral portion of the femoral head to allow insertion of femoral broaches (Figure 9).

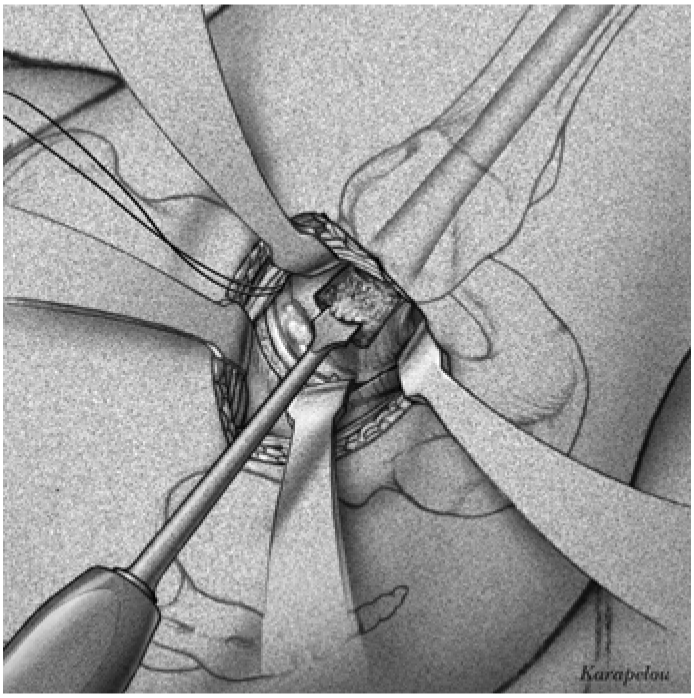


Figure 9.

Use broaches up to size and gauge the depth that the shoulder of the broaches are inset below the tip of the greater trochanter. The broach insertion handle may have a ruler etched on it to facilitate this estimation (Figure 10).

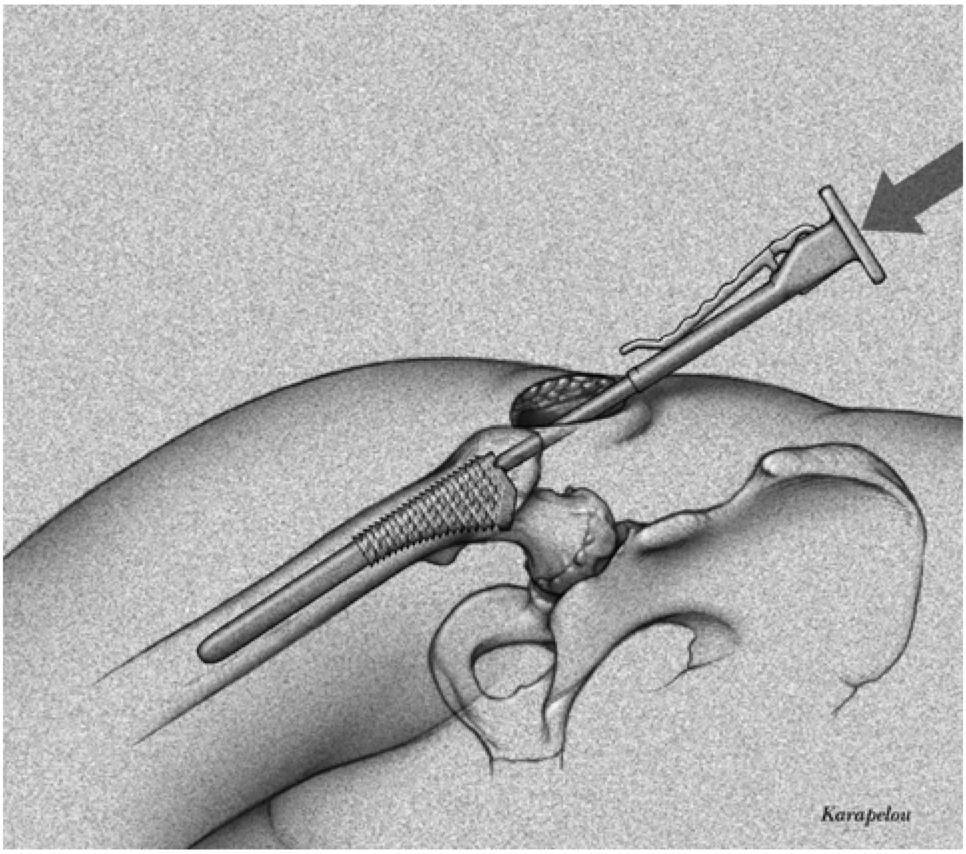


Figure 10.

This distance is typically 15 to 30mm but varies depending on the anatomy and preoperative leg length discrepancy. Once the final broach is fully seated, remove the broach handle.

Femoral Neck Osteotomy

Estimate the pre-reconstruction leg-length prior to removal of the femoral head. A pin in the pelvis measured to a point on the greater trochanter can be helpful. Use an oscillating saw with a narrow blade to transect the femoral neck, using the top of the broach as a template (Figure 11).

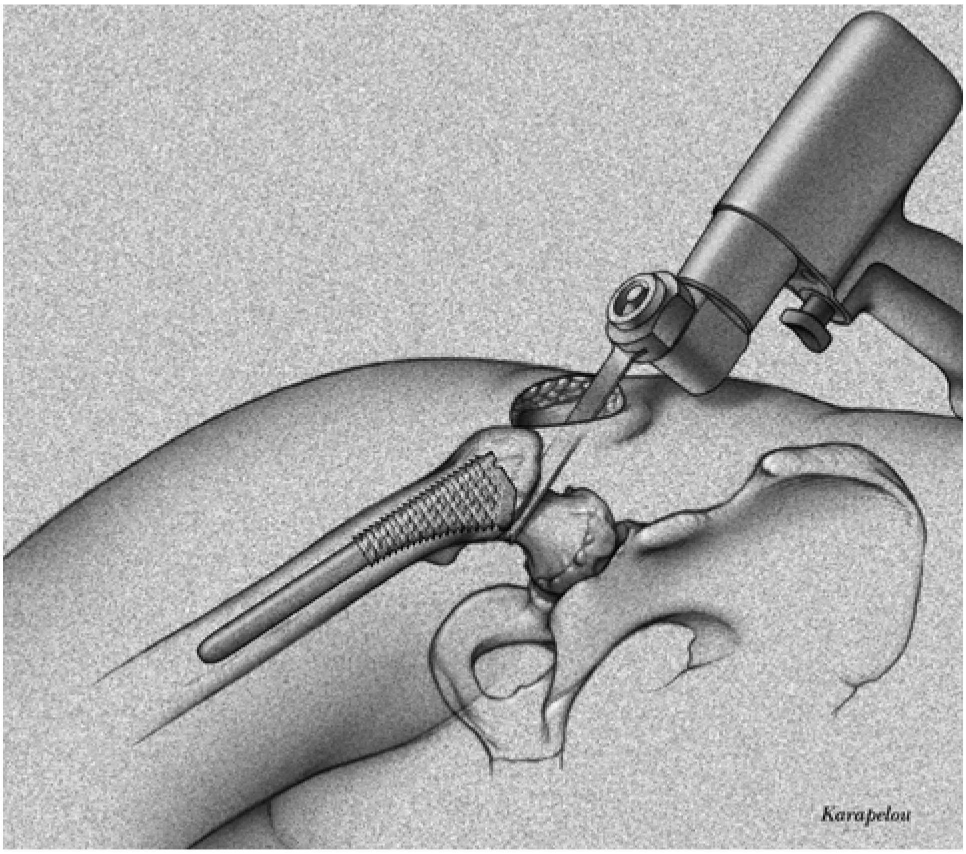


Figure 11.

The blunt Homan retractors serve to protect the surrounding tissues. The saw blade can be felt to penetrate the bone much the same way that a cast saw is used when removing a case. To ensure that the neck has been transected, place a Cobb elevator in the path of the saw blade and lever to ensure that the femoral neck cut has been completed.

Femoral Head Removal

Place a Cobb elevator at the head/socket junction and rotate the head into a little valgus. Place a long shanz screw into a solid part of the head (Figure 12).

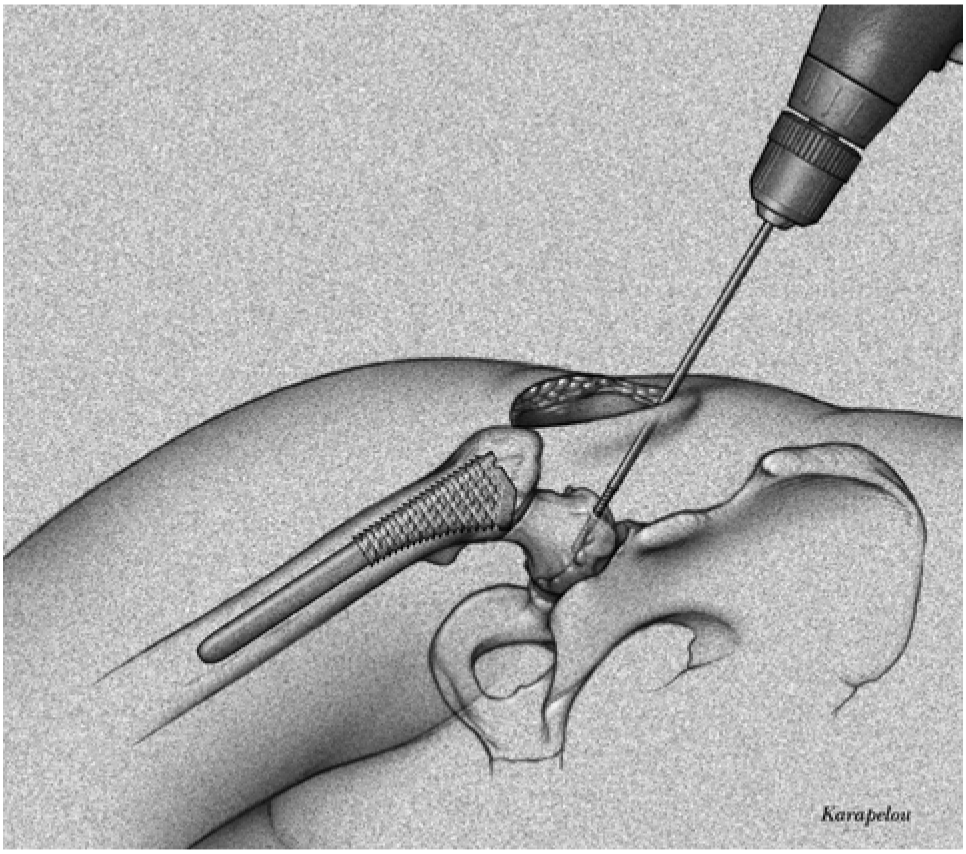


Figure 12.

Affix a T-handle chuck to the shanz screw and a slap-hammer to the T-handle chuck. Remove the spiked Homan that is in the posterior/superior portion of the head. Use the shanz screw to rotate the head into valgus which will facilitate subluxation (Figure 13) and the slap-hammer to extract the head.

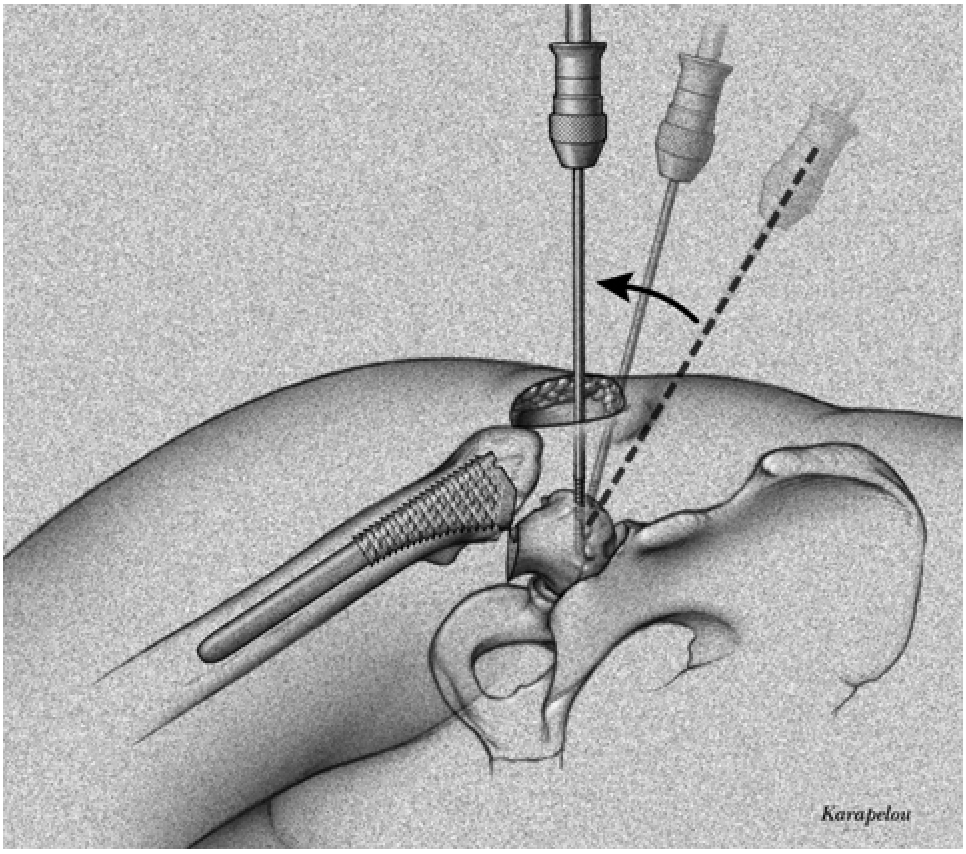


Figure 13.

Impact the two blunt Homan retractors through the capsule around the anterior and posterior portions of the acetabulum inferiorly. Move the sharp spiked Homan from the anterior ilium down to the mid-anterior socket time and impact it into the bone, deep to the capsule. Finally, carefully place a small spiked Homan retractor in the posterior/superior acetabular rim to complete the acetabular exposure. Remove the labrum. Trim the cut edge of the femoral neck if necessary.

Acetabular preparation and component insertion

Use the 45 degree angled acetabular reamer handle to ream the socket appropriately (figure 14).

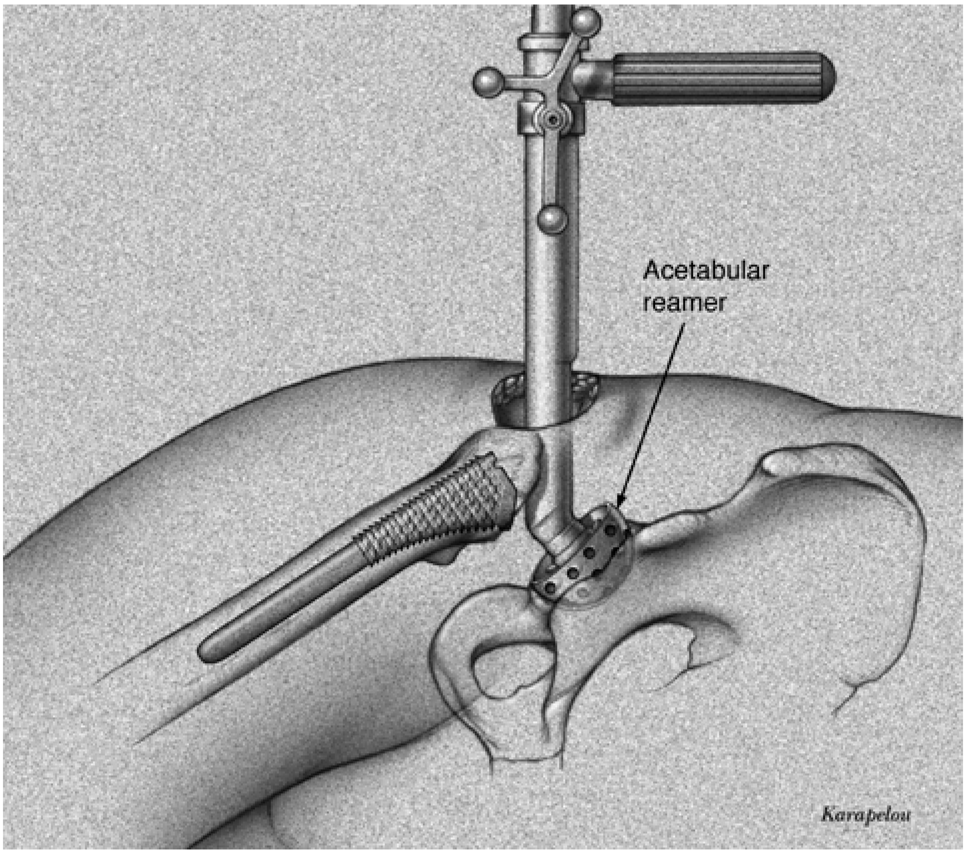


Figure 14.

Use the double-angled cup impactor to insert the cup (figure 15).

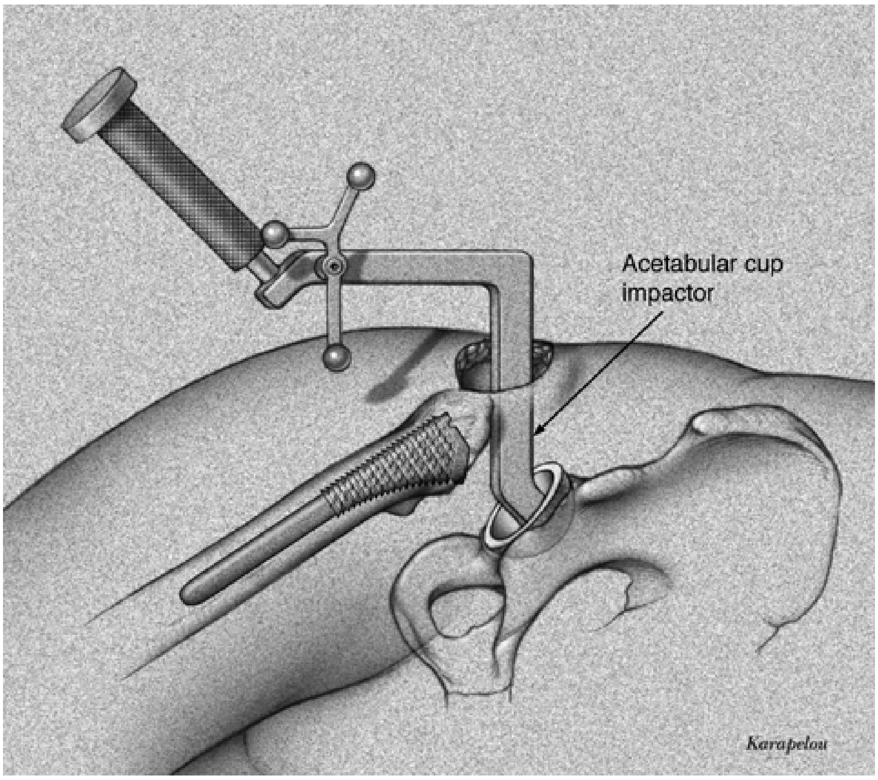


Figure 15.

Trial Reduction

After placing a trial liner into the cup, place the trial head into the socket. Switch to the anterior side of the table and place a large bone hook into the top of the broach trial. Controlling the leg and the bone hook, deliver the femur into position for your assistant to place the trial femoral neck into the broach. Reduce the neck into the trial head. The hip should be fully stable and undislocatable in any position.

Trial Disassembly and Final Component Insertion

Have your assistant hold the trial head within the socket using a long schnidt and, applying traction using the bone hook, disassemble the trial neck from the trial head. Remove the trial neck and broach. Insert the real prosthesis. Repeat the trial reduction as necessary. Remove the trial liner and impact the real liner using the double-angled cup impactor. Place the real head within the liner. Insert the real neck into the femoral prosthesis. Reduce the neck into the head.

Closure

Using the tagging suture in the anterior capsule, close the capsule using a running suture from proximal, at the acetabular rim, to distal, toward the trochanteric fossa followed by fascial and superficial layer closure.

Rehabilitation

The patient should be able to progress without restriction of motion. Progress weight bearing according to your confidence in the implant-bone fixation.

3. Total Hip Arthroplasty Performed Using Conventional and Tissue Preserving Techniques – A Prospective Study

Materials and Methods

115 consecutive total THA performed using a tissue preserving technique through a superior capsulotomy (study group) were prospectively compared to the 142 consecutive THA performed using a modified transgluteal exposure (control group). All procedures were performed by the same surgeon between October 1997 and December 2004. In order to have a control group of similar complexity to the study group, 14 of the 142 control cases were excluded as they were deemed too complex to have been performed using the superior capsulotomy technique. Reasons for exclusion included 7 hips with prior pelvic or femoral osteotomies with or without hardware, 4 with deformities too severe to have been safely performed using the superior capsulotomy technique, 1 with a prior vascularized fibula and hardware and 2 prior ORIF with hardware. This left a total of 128 cases for the control group that were of similar complexity to the 115 cases in the study group. Demographic data

including age, sex, height, weight, body mass index (BMI), preoperative diagnosis, pre-operative Merle d'Aubigné hip score, and previous surgeries were collected for all patients and are listed in Table 1.

Operative Technique for Study Group:

The technique of tissue-preserving total hip arthroplasty using a superior capsulotomy has been described above and previously [7,8]. Briefly, the surgery is performed through an incision in the superior capsule, posterior to the gluteus medius and minimus and anterior to the posterior capsule and short external rotators. Only the piriformis insertion is detached. The femur is prepared through the superior neck before the femoral head is removed. Following component implantation, the capsule is closed and the patients are allowed unrestricted motion and progression of weight bearing. All patients in the study group had surgery performed with CT-based surgical navigation of acetabular component insertion.

Operative Technique for Control Group:

For the control group, the transgluteal exposure was performed in the lateral position. The anterior 1/3rd of the medius, entire minimus, and anterior ½ of the hip joint capsule is reflected anteriorly with a thin bony wafer of the anterior part of the greater trochanter. The procedure is then performed in a conventional manner by dislocating the hip, excising the femoral head, preparing and inserting the acetabular component with straight instruments, and then preparing and inserting the femoral component with straight instruments. Following implantation, the superior capsule is closed and the abductors are repaired with simple and horizontal mattress transosseous sutures. Post-operatively, patients are allowed unrestricted range of motion, but are asked to continue 50% weight-bearing with two crutches for 6 weeks. None of the patients in the control group had surgery performed with surgical navigation.

Anesthetic management and rehabilitation protocols.

No changes in anesthesia or post-operative pain control were instituted during the period of this study. Rehabilitation in the two groups did differ. Both groups were allowed to progress their hip motion as tolerated without restriction. The control group (transgluteal exposure) patients were cautioned against abduction against gravity or progression to full weight-bearing until at least six weeks after surgery to protect the abductor repair. The study group (superior capsulotomy exposure) were allowed to progress to full weight-bearing as tolerated.

Pre- and Post-Operative Assessment.

Both groups were studied prospectively using the same standardized hip function questionnaires, the same examination parameters, and the same radiographic views, pre-operatively, and at each visit post-operatively. All patients completed the hip questionnaires at each visit including information about pain and functional status and were evaluated clinically by the operating surgeon. These evaluations were performed pre-operatively and at the first and second visits post-operatively. Post-operative visits that occurred at up to 9 weeks following surgery were included in the 1st follow-up visit analysis. Post-operative visits that occurred from 9 to 24 weeks were included in the 2nd follow-up visit analysis. The Merle d'Aubigné hip score[9] was calculated for each patient at each visit. The acetabular cup abduction was measured on a postoperative AP pelvic radiograph with the interteardrop line as a horizontal reference by one single examiner blinded to the study group. The length of hospital stay and the disposition following discharge were recorded.

Statistical analysis

Fisher's exact test was used to analyze nominal data between the study and control groups. Continuous data between these two groups were analyzed with the nonparametric Mann-Whitney U-test. Differences of standard deviation of the cup abduction angles between the two study groups were calculated with the F-test. Values of $p < 0.05$ were regarded as statistically significant.

Results

Demographic data

There were no significant differences between the study and control groups with regard to patient gender, operated side, number of patients with bilateral hip-surgery, diagnosis, patient height and number of previous operations (Table 1).

However there were statistically significant differences in patient age, patient weight, BMI and preoperative Merle d' Aubigné Score (Table 1).

Patients in the study group were older and had lower average in the preoperative Merle d' Aubigné Score, whereas patients in the control group had higher body weight and BMI. These results occurred although the groups where assembled consecutively, randomized and without any consideration of certain parameters.

Clinical and radiographic results

Clinical and radiographic results are shown in Table 2. There were no statistically significant differences in length of hospital stay ($p = 0.827$) and the percentage of patients who were discharged directly home after hospitalization ($p = 0.784$). Mean first follow up was at 6.0 weeks for the study group and 6.3 weeks for the control group ($p = 0.085$). Mean second follow up was 15.8 weeks for the study group and 14.1 weeks for the control group ($p < 0.0001$).

The mean cup abduction angle was 43.6° for the study group and 41.6° for the control group (Table 2). The difference was statistically different ($p < 0.0001$). Further, the standard deviation in cup abduction was 3.6 for the study group and 4.7 for the control group. The smaller standard deviation in the study group was also statistically different ($p = 0.009$).

Assessment post-operatively demonstrated a statistically significant improvement in the Merle d'Aubigné hip score at the 1st follow up visit for the study group as compared to the control group (Fig. 13). Moreover the Merle d'Aubigné hip score at the 2nd follow-up visit was also statistically significantly different with an advantage for the study group (Fig. 16).

Complications

There were 3 surgical complications (2.6 %) in the study group and 6 in the control group (4.7 %). However, this lower incidence of surgical complications for the tissue-preserving group was not statistically significant ($p > 0.05$). One patient (0.9 %) had to be reoperated in the study group, 4 patients (3.1%) needed reoperation in the control group. This difference was not statistically significant ($p > 0.05$).

The three surgical complications for the study group comprise one intraoperative greater trochanteric fracture treated at the time of surgery; one patient had unrecognized displacement of the acetabular component during surgery requiring acute correction. There was one acute dislocation immediately after surgery. The patient was revised and treated with a larger diameter femoral bearing component.

Among the six complications for the control group, there were 2 trochanteric wafer nonunions, both of them requiring repair. Two patients had an intraoperative trochanteric fracture which was fixed during surgery. Two patients required incision and drainage for acute deep infection.

Discussion

Total hip arthroplasty in its many conventional forms is extremely reliable with low complication rates. Attempts to perform total hip arthroplasty through smaller incisions or through more tissue-preserving intervals can easily result in an increase operative complications rather than a decrease. Even if the majority of patients treated by less invasive techniques recover more rapidly, the benefits may be outweighed if there is even a small increase in the incidence of complications.

However, conventional methods of total hip arthroplasty have disadvantages that can be addressed. The posterior exposure, whether through a small or large incision, has the disadvantage that the posterior capsule and short rotators are transected at surgery. Whether these structures are meticulously repaired or not, these patients are generally not safely allowed to progress to unrestricted motion following surgery. Further, anatomic healing of the posterior capsule and short rotators following the posterior exposure cannot be assured [10-12]. Conversely, the transgluteal exposure has the disadvantage that a portion of the abductors are mobilized and repaired at surgery [13,14]. This means that early full weight bearing cannot be allowed without risking abductor injury and its associated consequences. The anterior exposures have the disadvantage that the minimus tendon and anterior border of the gluteus medius prevent direct access to the femur and can therefore be injured with the technique [2,15,16]. Further, the lateral femoral cutaneous nerve, while not critical for function, is often adversely affected.

Protecting the abductors, posterior capsule, and short rotators as much as possible during surgery is a reasonable goal of tissue-preserving surgery. Performing a total hip arthroplasty, while minimizing adverse affects on these structures, undoubtedly results in a more technically challenging procedure. However, the current study demonstrates that total hip arthroplasty performed through a superior capsulotomy with surgical navigation can simultaneously accelerate recovery, while potentially reducing the incidence of complications as compared to a conventional transgluteal exposure without surgical navigation. These finding are particularly notable since the procedures in the control group were performed after an experience of many hundreds of procedures while the procedures in the study group were performed during not only the learning-curve phase but during the period where the procedure was being refined.

The study group had the surgery performed with the femoral component instrumented before femoral neck osteotomy and femoral head removal. This technique has several advantages over traditional total hip replacement surgery. First, the femur remains steady during the femoral instrumentation. Second, leverage retractors around the neck are easy to hold to maintain exposure. Third, the femur is clearly stronger with the head and neck intact and is more difficult to crack during instrumentation. Finally, the leg is never placed into a position that outside of the normal range of motion of the hip which may have positive implications for the health of the surrounding soft-tissues and for venous return during the procedure.

One clear weakness of the study is the fact that the study group was not compared to a group of patients treated by a posterior exposure. It is likely that patients treated by a posterior exposure would recover more quickly than those treated by a transgluteal exposure. However, on balance, it is evident that a hip replaced with the posterior capsule and short rotators left intact is a more stable hip than one performed with these structures sacrificed with attempted repair. All of the patients in both the study and control groups had surgery performed with the goal of preserving the posterior capsule and short rotators during surgery. There was only one dislocation in the study group despite recommending progression of motion without restriction post-operatively. This dislocation happened immediately after surgery and was due to shortening of the leg that was acutely corrected by inserting a longer modular neck. Further comparison of the posterior exposure with capsular repair to the superior capsulotomy exposure is clearly necessary. Another weakness of the study is that the rehabilitation protocol for the two groups was not identical. An argument could be made that hips following a transgluteal exposure would rehabilitate more quickly if full weight bearing were allowed right away. Our results however show that abductor injury following the transgluteal exposure remains a concern and that accelerated weight bearing following this technique is clearly ill-advised.

Both the study and control group had acceptable acetabular component abduction angles with low standard deviations. Since all of the procedures in the control group were performed with surgical navigation, it is reasonable to conclude that surgical navigation played a role in maintaining good acetabular component positioning with even statistically smaller standard deviations, despite the use of a small incision. This study does not allow the conclusion that cup positions would remain satisfactory if the superior capsulotomy technique is used without surgical navigation. Further studies of total hip arthroplasty through a superior capsulotomy, without surgical navigation, would be necessary to determine if cup position would be adversely affected by the technique.

The fact that the pre- and post-operative physical examinations were performed by the operating surgeon creates inherent bias. The fact that the majority of the parameters measured were either answered by patient on the questionnaire or measured by an independent observer in the medical record or radiographs serves to minimize this bias. The two parameters that could be biased are assessment of range of motion and limp after surgery. This study however did not demonstrate any difference in range of motion between the two groups. Further, since the use of walking aids was defined by the patient, introduction of bias regarding limp would likely have little effect on the conclusions of the study.

In summary, total hip arthroplasty performed through a superior capsulotomy with surgical navigation offers promise that it may have all of the hip joint stability advantages of the transgluteal and all of the abductor recovery advantages of the posterior exposure. While it has yet to be proven that this technique can be safely taught and produce the same results at other medical centers, the current study demonstrates the potential that less invasive, tissue-preserving techniques can simultaneously accelerate recovery, while reducing the incidence of perioperative complications.

Tables and Figures:

Table 1.) Demographic Data

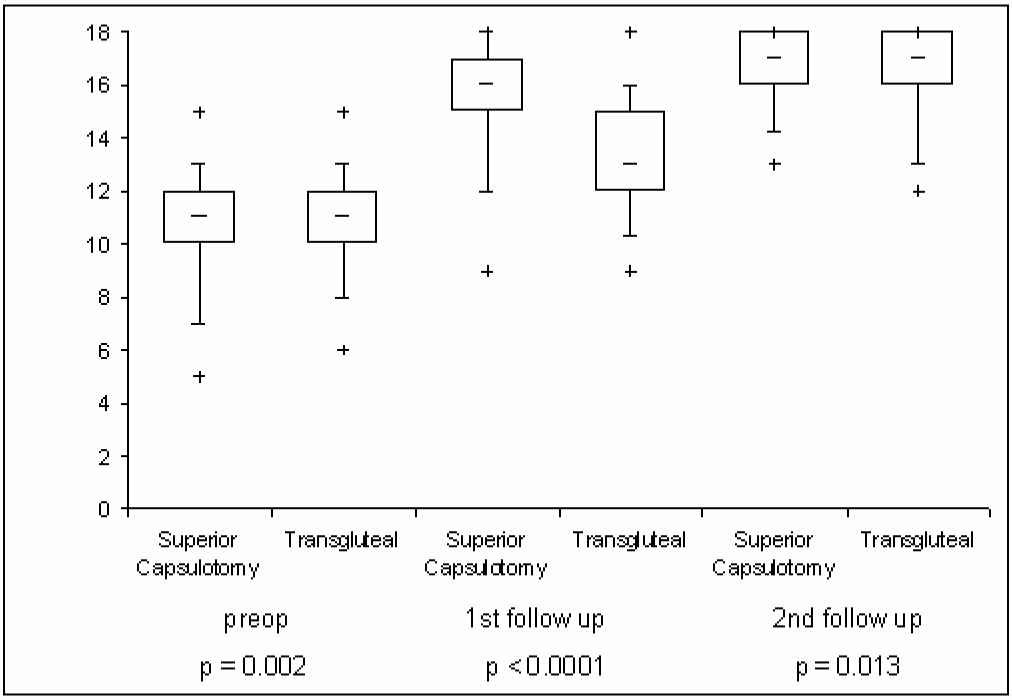
Parameter	Study group	Control group	p-value
Total number of hips	115	128	
Age [years]	55.6 ± 12.0 (20.1 - 84.5)	51.4 ± 11.3 (20.5 - 76.5)	0.005
Gender [m / f / % male]	62 / 53 / 53.9	68 / 60 / 53.1	0,902
Side [l / r / % right]	48 / 67 / 58.3	62 / 66 / 51.6	0.296
Bilateral hips (no. / % bilateral)	18 / 15.7	20 / 15.6	0.995
Preoperative Diagnosis Osteoarthritis Dysplasia Osteonecrosis Other	 83 (72.2 %) 25 (21.7 %) 4 (3.5 %) 3 (2.6 %)	 94 (73.4 %) 26 (20.3 %) 5 (3.9 %) 3 (2.3 %)	0.841
Height [cm]	171 ± 10.5 (145-191)	171 ± 11.5 (142 - 195)	0.982
Weight [kg]	78.7 ± 18.8 (36.4 - 129.5)	85.2 ± 20.8 (45.5 -136.4)	0.032
BMI [kgm^2]	26.7 ± 4.9	29.2 ± 6.9	0.002

	(17.3 - 39.2)	(18.3 - 56.2)	
No. of hips with previous surgery	5 (4.4 %)	6 (4.7 %)	
Pelvic Osteotomy	2	1	
Trochanteric Osteotomy	1	2	
ORIF	1	2	0.401
Core Decompression	1	-	
SHELF	-	1	
pre-OP Merle d' Aubigné Score	10.5 ± 1.7 (5-15)	11.1 ± 1.7 (6-15)	0.002

Table 2.) Radiographical, Hospital and Recovery Data

Parameter	Study Group	Control group	P value
Incision length	7.8 ± 2.0	not measured	
Cup abduction [°]	43.6 (35 – 55)	41.6 (26 – 54)	< 0.001
Standard deviation cup abduction	3.6	4.7	0.009
Length of stay [d]	3.8 ± 1.0 (2 - 10)	4.0 ± 1.6 (2 – 11)	0.827
Disposition (home / rehabilitation) [% home]	76.5	78.2	0.784
Merle d'Aubigné preoperative	10.5 ± 1.7 (5-15)	11.1 ± 1.7 (6-15)	0.002
Merle d'Aubigné 1st follow up	15.3 ± 1.8 (9 - 18)	13.4 ± 1.8 (9 – 18)	< 0.0001
Merle d'Aubigné 2nd follow up	17.0 ± 1.2 (13 – 18)	16.4 ± 1.5 (12 – 18)	0.013
Complications	3 (2.6 %)	6 (4.7 %)	
Intraoperative Cup-Dislocation	1	-	
Intraoperative Greater Trochanteric Fracture	1	2	> 0.05
Trochanteric wafer non-reunion	-	2	
Incision and Drainage	-	2	
Acute Dislocation	1	-	

Figure 16.) Significantly Improved Follow Up Results in the Merle d' Aubigne Score



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