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Clinical and functional comparison between different surgical approaches to total hip arthroplasty

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INDEX

INTRODUCTION

1. Total hip arthroplasty

Total hip arthroplasty (THA) has been one of the most successful orthopaedic procedures over the past 30 years [1, 2]. This procedure involves the surgical excision of the head and the proximal neck of the femur, and the removal of the acetabular cartilage and subchondral bone. An artificial canal is created in the proximal medullary region of the femur, and a metal femoral prosthesis, composed of a stem and a small-diameter head, is inserted into the femoral medullary canal. An acetabular component is inserted proximally into the enlarged acetabular space. To yield successful results, these THA components must be fixed firmly to the bone, either with polymethylmethacrylate cement or, in more recent uncemented designs, by allowing bone ingrowth into a porous coating on the implant, resulting in a "biologic" fixation. The first THA is thought to have been performed in 1938 by Philip Wiles at the Middlesex Hospital in London [3]. The procedure was further developed in the 1950s by pioneers such as McKee and Farrar [4]. This early work laid the groundwork for the innovative studies of Sir John Charnley who, in the late 1960s, approached the problem of artificial hip joint design by using the biomechanical principles of human hip joint function [5, 6]. Repeated trials and experimentation with various materials and prosthetic designs culminated in the creation of the Charnley low-friction arthroplasty, a procedure still considered by many to be the current standard of total hip replacement. Since Charnley's original prosthesis

was introduced, several variants of the artificial hip joint have been developed; however, none of these have proved to be superior in the clinical setting.

2. Noncemented THA

Noncemented THA (N-THA) has gained popularity particularly among younger patients, because of the simplicity of surgery, preservation of bone stock and longevity of the implants [7]. N-THA was developed in response to evidence on cement debris playing an important role in promoting bone lysis and loosening. Prosthetic devices that achieve fixation without cement either by “press-fit” or by biologic ingrowth have successively been developed. With the press-fit technique, stabilization is achieved by ensuring an optimal interference fit of the implant into the femur and the acetabulum. With biologic ingrowth, fixation occurs by bone ingrowth into a porous surface.

The first generation of uncemented femoral components had a high incidence of osteolysis, thigh pain, aseptic loosening, and need for revision. The newer generation has a tapered design that achieves primary press fit fixation in the proximal femoral diaphysis, with a load transmission comparable to that of the normal femur [8]. The rationale for such tapered stems is in fact based on the self-locking principle, combined with a low modulus of elasticity, and fixation in the proximal femoral diaphysis. The cementless Spotorno (CLS) stem is straight with a continuous medial arch, and an undersized tip designed to avoid distal cortical fitting. This prevents the stress concentration effect at the tip of

the prosthesis. Primary stability is accomplished by supporting the proximal stem in a retained bed of both cortical and trabecular bone. The ALLOFIT cup is a pure titanium shell with a polyethylene liner. It has a flattened hemispherical shape with sharp edged barbed overlaps and polar circular cutting ring segments. The press-fit fixation provides primary mechanical stability until secondary biological osteointegration (bone ingrowth) occurs.

3. Minimally invasive surgery

Recently there has been an increasing interest in minimally invasive approaches to hip replacement [9, 10]. The concept of minimally invasive surgery (MIS) in joint replacement refers to a reduction of surgical damage to the periprosthetic soft tissue, achieved by using smaller standard surgical incisions; these include the direct lateral, anterior and posterolateral approaches [11]. There is continued controversy among orthopaedic surgeons regarding which of these surgical approaches is best for primary THA, due to the fact these approaches all have distinct advantages and limitations. A Cochrane review by Jolles and Bogoch [12] concluded that despite the numerous studies examining the effect of the different surgical approaches on THA results, the quality and quantity of such trials were insufficient to reach a definitive conclusion on whether one approach was superior to the others. In particular, of the four prospective cohort studies included in this Cochrane review, only the one by Barber et al. [13] included data on functional outcomes obtained with the use of the Harris Hip Score (HHS) with a short follow-up period of

two years; additionally, this study included only 49 patients. The effect of the type surgical approach on dislocation rates after primary THA has also been the primary focus of numerous studies [14, 15], but to date, there is no firm consensus on which approach is actually associated with higher dislocation rates. The effect of surgical approach on revision rates after primary THA is also subject to debate. It has been hypothesised that the type of surgical approach employed may affect implant failure rates [16]. In critically evaluating THA approaches, one must compare their features to the ideals of a “perfect approach”. Such technique should be easy to understand, teach and perform, while allowing precise, reproducible implantation of various prosthetic options (cemented, cementless, proximal fit or distal fit). Additionally, long-term results ultimately need to be equal to, or better than the current gold standard. In order to be universally accepted, the approach must require a minimal number of assistants and involve only a nominal risk to the surrounding neurovascular structures. The overall goals should be to decrease pain, length of hospital stay and time to ambulatory independence, while yielding negligible risk for concomitant morbidities.

4. Epidemiology

Since 2002, the Italian National Institute of Health (*Istituto Superiore di Sanità; ISS*) has been involved in several studies on hip arthroplasties. In Italy, more than 90,000 of such surgical procedures are performed every year, with an estimated cost of around 800 million Euros. The interest of the public health sector on this subject is motivated by the fact

that in recent years, there has been a considerable increase in the number of hip surgeries in Italy, Europe and the rest of the world. The statistical office of the *ISS* has collected the results of an analysis of the nationwide hospital database (*SDO*, or hospital discharge records) for the period between 2001 and 2007, including the ICD9-CM codes (International Classification of Diseases, 9th revision, Clinical Modification) for primary and revision hip replacement surgery (8151=full replacement; 8152=partial replacement; 8153=replacement of revision) (these data are presented in Tables 1-4). For each code, the number of surgeries performed each year was calculated, and the mean age and the sex of the patients were noted. For example, in the Santa Maria del Prato Hospital in Feltre (Belluno - Italy), the number of prosthetic hip surgeries has risen from 205 in 2006 to 296 in 2009 (Tab. 5).

Cod.	Denominazione	2001	2002	2003	2004	2005	2006	2007	2008
Anca									
81.51	Sostituzione totale dell'anca	46.839	49.800	52.549	55.812	57.055	59.249	60.405	60.835
81.52	Sostituzione parziale dell'anca	21.459	22.090	21.775	22.473	23.243	23.278	23.125	23.911
81.53	Revisione di sostituzione dell'anca	6.143	6.633	6.684	6.897	7.125	7.403	7.498	7.438
	Totale	**74.441**	**78.523**	**81.008**	**85.182**	**87.423**	**89.930**	**91.028**	**92.184**
	% sul totale	*70,55%*	*68,54%*	*66,14%*	*63,99%*	*62,70%*	*61,16%*	*59,41%*	*58,58%*
Ginocchio									
81.54	Sostituzione totale del ginocchio	27.372	31.674	36.618	42.017	45.049	49.484	54.002	56.642
81.55	Revisione di sostituzione del ginocchio	1.290	1.675	1.941	2.245	2.525	2.755	3.123	3.433
	Totale	**28.662**	**33.349**	**38.559**	**44.262**	**47.574**	**52.239**	**57.125**	**60.075**
	% sul totale	*27,16%*	*29,11%*	*31,48%*	*33,25%*	*34,12%*	*35,52%*	*37,29%*	*38,17%*
Spalla									
81.80	Sostituzione totale della spalla	716	822	952	1.265	1.464	1.687	2.005	2.183
81.81	Sostituzione parziale della spalla	855	885	925	1.038	1.058	1.194	1.191	1.238
	Totale	**1.571**	**1.707**	**1.877**	**2.303**	**2.522**	**2.881**	**3.196**	**3.421**
	% sul totale	*1,49%*	*1,49%*	*1,53%*	*1,73%*	*1,81%*	*1,96%*	*2,09%*	*2,17%*
Altre articolazioni									
81.56	Sostituzione totale della tibiotarsica	96	116	150	176	178	257	268	287
81.57	Sostituzione dell'articolazione del piede e dell'alluce	316	398	409	458	630	635	680	710
81.59	Revisione di sostituzione di articolazione delle estremità inferiori, non classificata altrove	218	189	185	361	700	591	383	154
81.73	Sostituzione totale del polso	44	45	46	50	63	87	74	75
81.84	Sostituzione totale del gomito	92	150	164	214	254	323	321	318
81.97	Revisione di sostituzione di articolazione dell'arto superiore	82	81	86	109	94	106	136	151
	Totale	**848**	**979**	**1.040**	**1.368**	**1.919**	**1.999**	**1.862**	**1.695**
	% sul totale	*0,80%*	*0,85%*	*0,85%*	*1,03%*	*1,38%*	*1,36%*	*1,22%*	*1,08%*
TOTALE		**105.522**	**114.558**	**122.484**	**133.115**	**139.438**	**147.049**	**153.211**	**157.375**

Table 1: Orthopedic prosthetic replacements performed in Italy from 2001 to 2008. Breakdown by type of surgical treatment (www.riap.info).

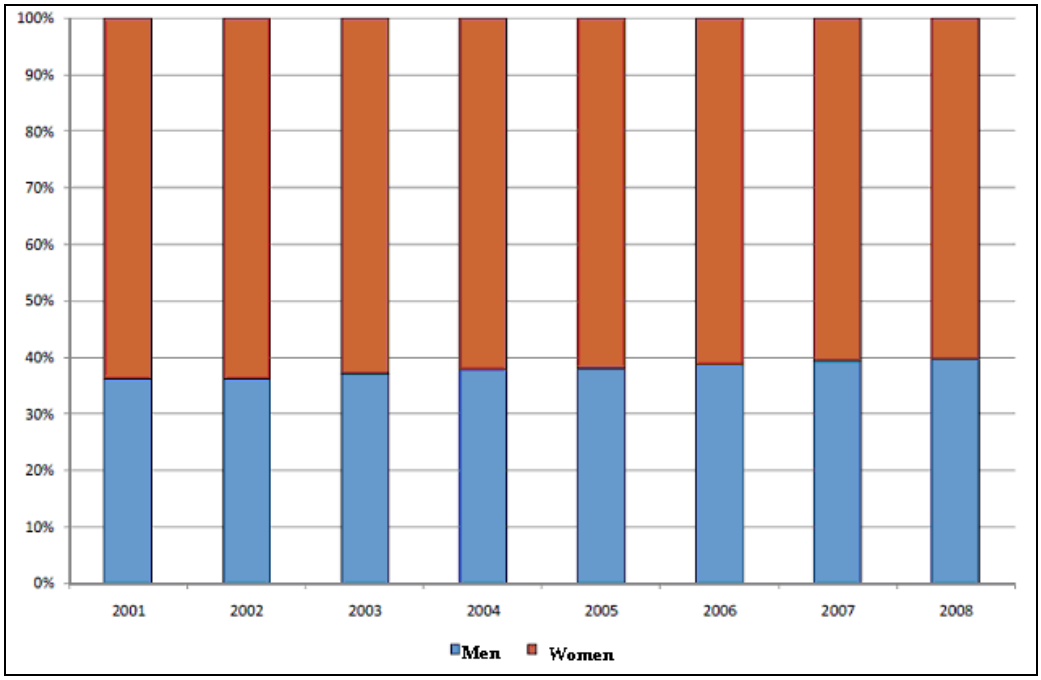


Table 2: Statistical distribution of replacement or total hip arthroplasty (ICD9-CM: 8151) by patient gender from 2001 to 2008.

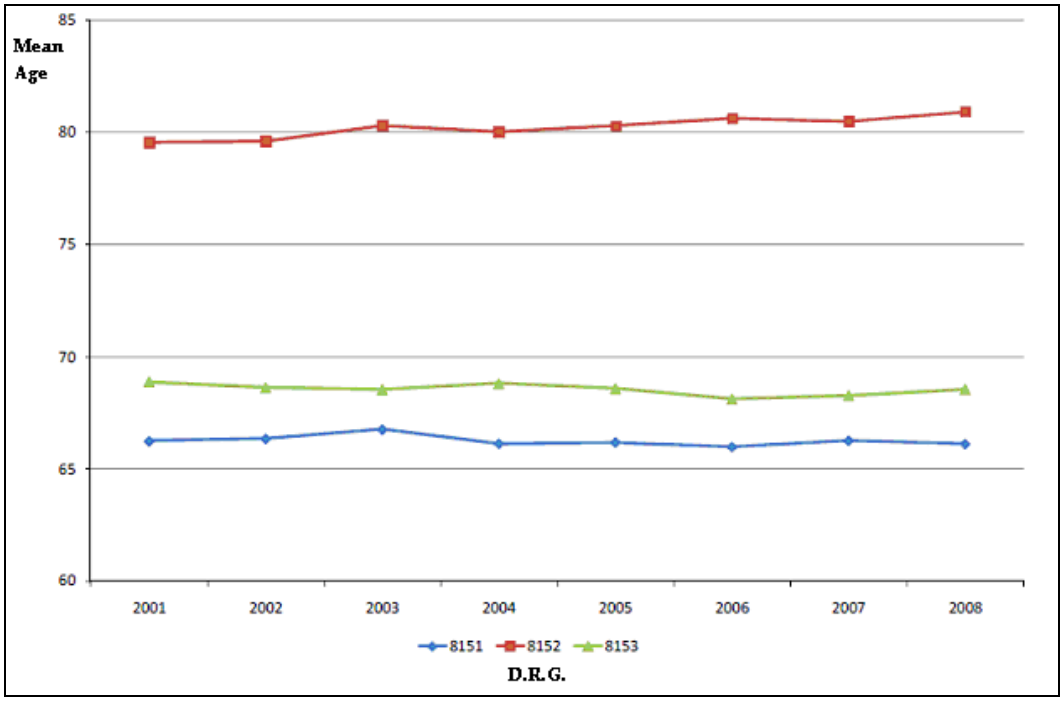


Table 3: Mean age of male patients who underwent hip replacement surgery (ICD9-CM: 8151, 8152, 8153) between 2001 and 2008.

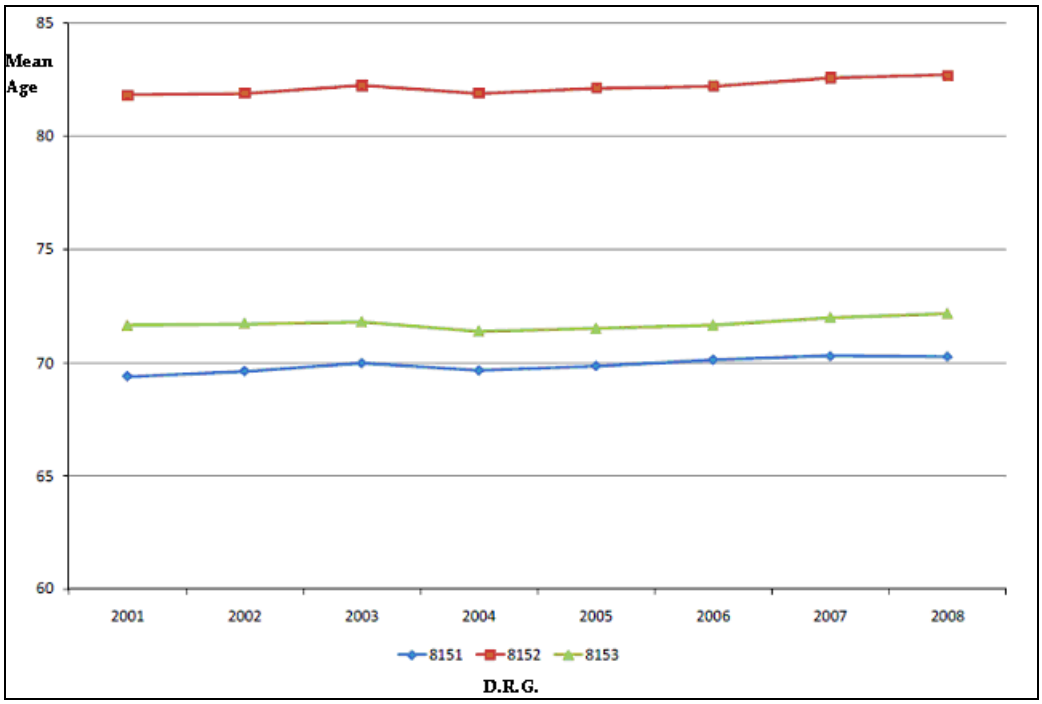


Table 4: Mean age of female patients who underwent hip replacement surgery (ICD9-CM: 8151, 8152, 8153) between 2001 and 2008.

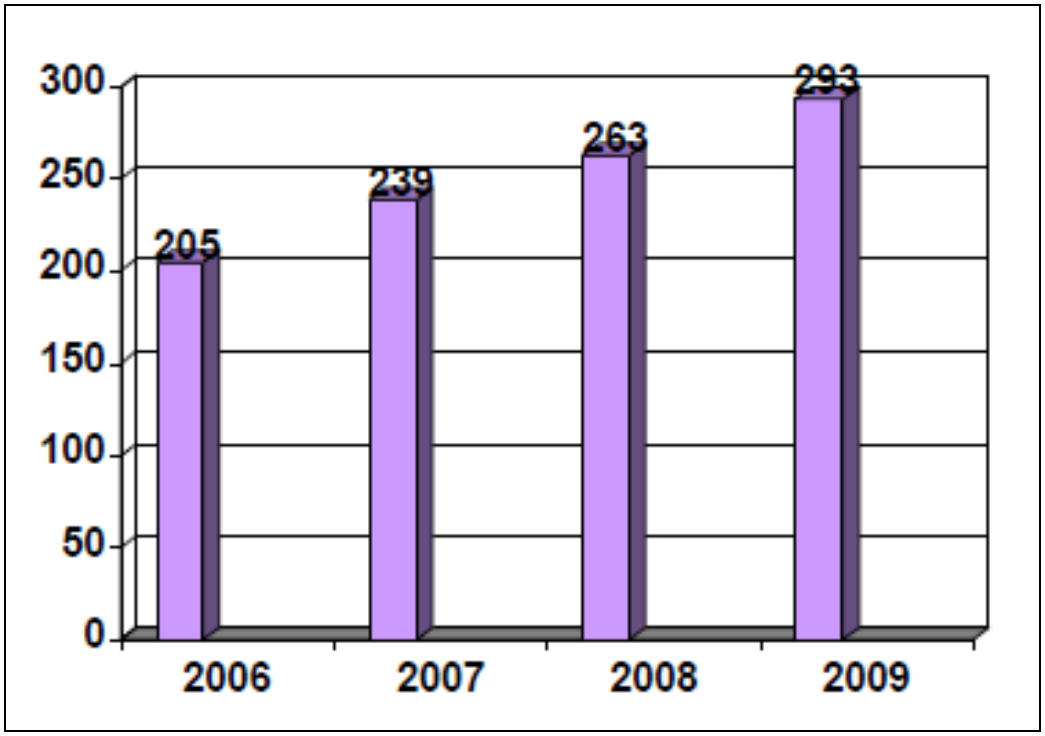


Table 5: Replacement or total hip surgery at the Department of Orthopedics and Traumatology of the Santa Maria del Prato Hospital in Feltre (Belluno - Italy) between 2006 and 2009.

5. THA: Indications and goals

THA is most commonly used for hip joint failure caused by osteoarthritis (Fig. 1); other indications include, but are not limited to, rheumatoid arthritis, avascular necrosis, traumatic arthritis, certain hip fractures, benign and malignant bone tumors, arthritis associated with Paget's disease, ankylosing spondylitis and juvenile rheumatoid arthritis. The aims of THA are pain relief and functional improvement.

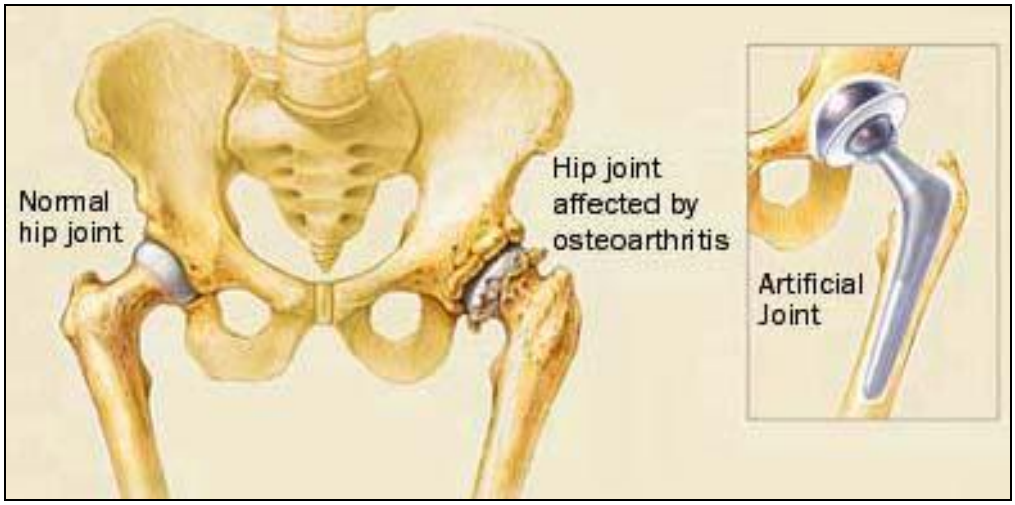


Fig.1: Osteoarthritis of the hip and total hip replacement (figure reproduced from http://osteoarthritis.about.com/).

Candidates for elective THA should have radiographic evidence of joint damage, as well as moderate to severe persistent pain and/or disability, that is not substantially relieved by an extended course of nonsurgical management. These measures usually include trials of analgesic and nonsteroidal anti-inflammatory drugs (NSAIDs), physical therapy, the use of walking aids and reduction of physical activities that provoke discomfort. In certain conditions, such as rheumatoid arthritis and Paget's disease, additional disease-specific therapies may be

appropriate. The patient's goals and expectations should be ascertained prior to THA in order to determine whether they are realistic and attainable by the recommended therapeutic approach. Any discrepancies between the patient's expectations and the likely outcome should be discussed in detail with the patient and family members before surgery. In the past, patients between 60 and 75 years of age were considered to be among the best candidates for THA. Over the last decade, however, the age range has been broadened to include more elderly patients, many of whom have a higher level of comorbidities, as well as younger patients, whose implants may be exposed to greater mechanical stress over an extended period of time. In patients under 55 years of age, alternative surgical procedures such as fusion and osteotomy should be considered. However, current data does not prove that the outcomes of these procedures are comparable to, or better than those obtained with THA when performed for similar indications. Advanced age alone is not a contraindication for THA; poor outcomes appear to be more closely related to comorbidities rather than to age. There are few contraindications for THA other than active local or systemic infection, along with other medical conditions that substantially increase the risk of serious perioperative complications or death. Obesity has been considered a relative contraindication because of a reported higher mechanical failure rate in heavier patients; however, the prospect of substantial long-term reduction in pain and disability in heavier patients appears to be similar to that in the general population. Thus, although the clinical conditions and circumstances leading to THA are

largely defined, several issues regarding indications remain unresolved. For example, current data on the association between potential risk factors (e.g., age, weight, smoking and medications) and outcomes are insufficient to guide treatment decisions for the individual patient. Moreover, it is not clear which indications should be taken into consideration for the choice between the various surgical approaches and types of prostheses in individual patients. Finally, standardized instruments to measure pain levels, physical disability, and quality of life as perceived by the patient, need to be used to guide clinical decision making and choice of surgical approach.

6. Surgical approaches

Currently, several surgical approaches for hip arthroplasty have been defined; these include the anterior, the lateral and the posterolateral approaches. The basic premise of these approaches is the use of a smaller skin incision (defined as less than 10 cm) to create a mobile window that allows an intermittent complete visualization of the surgical anatomy. The same respective surgical approach and bone resection are performed beneath the skin incision. Overall, there is conflicting data available regarding the efficacy of these approaches in terms of need for blood transfusions, pain control, length of hospital stay, and duration of the recovery period [17, 18]. However, most studies have reported improved cosmesis and patient satisfaction with such approaches involving smaller incisions [19]. Howell and colleagues lent significant

importance to the psychological impact of improved cosmesis on patient attitude, satisfaction and motivation for recovery, and cautioned that this appeal should not be underestimated [20].

6.1 Anterior Approach (Smith-Petersen)

The anterior approach to THA, first described by Smith-Petersen, utilizes the internervous plane located between the sartorius (femoral nerve) and the tensor fascia latae (superior gluteal nerve) superficially, and between the rectus femoris (femoral nerve) and the gluteus medius (superior gluteal nerve) at a deeper level [21]. The patient is first placed in a supine position on the operating table (fig. 2), and a folded towel is placed under the operative hemipelvis. This allows the pelvis to be brought forward for easier access.

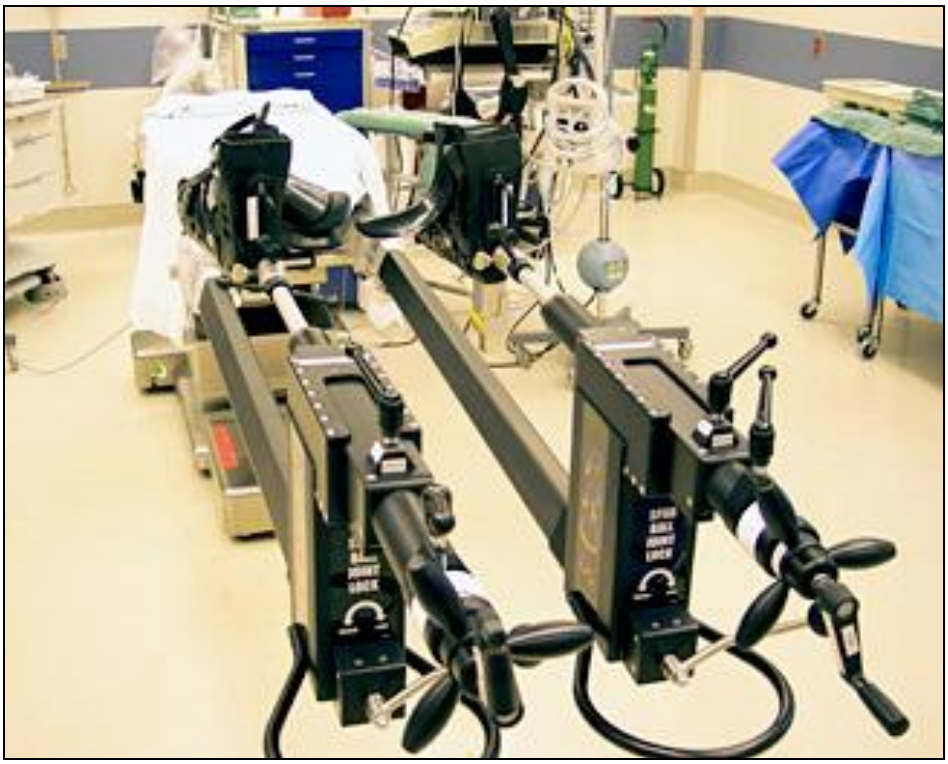


Fig. 2: Operating table used for the anterior approach.

Next, a skin incision is made from the middle of the iliac crest, and curved towards the anterior superior iliac spine. The incision is then curved distally and laterally to finish below the level of the lesser trochanter (fig. 3).

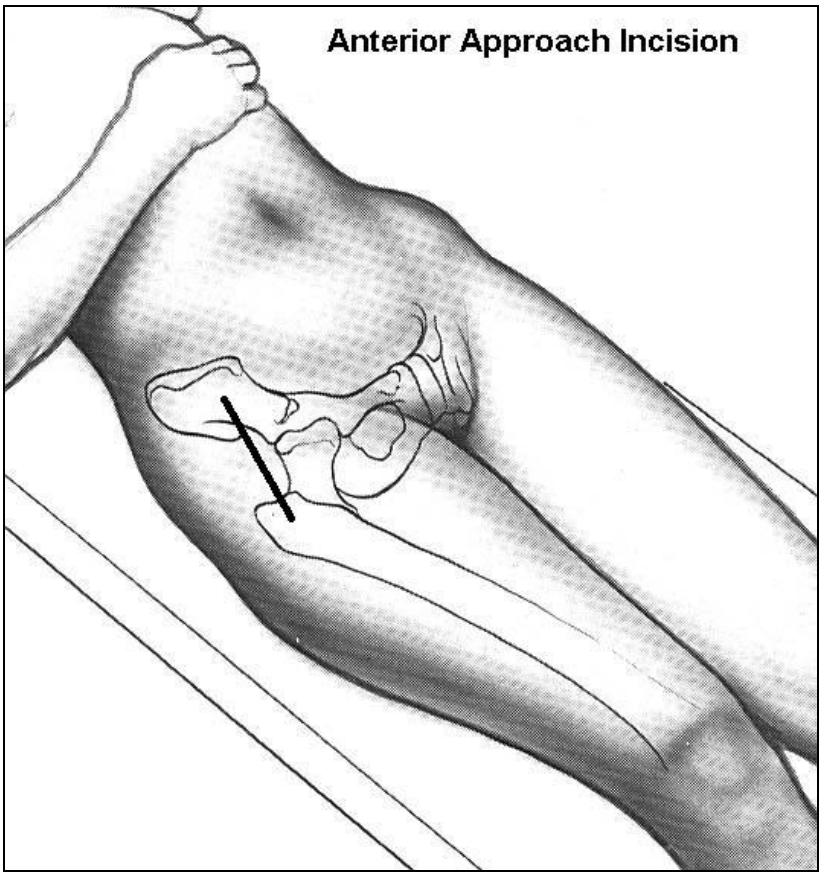


Fig. 4: Anterior approach incision (figure reproduced from www.orthopedics.com).

The location of the lateral femoral cutaneous nerve must be taken into consideration in this approach in order to preserve lateral thigh sensation. It exits about 1 cm medial and below the anterior superior iliac, and passes over the sartorius.

The tensor fascia latae and gluteus medius muscles are successively detached from the iliac crest and elevated subperiostially from the lateral wing of the ilium. Dissection is continued through the deep fascia to

visualize the position of the tensor fascia latae laterally, and the rectus femoris and sartorius muscles medially. In this space, the ascending branch of the lateral femoral circumflex artery may be encountered and should be ligated for haemostasis. The interval between the rectus femoris and tensor fascia latae is then opened (fig. 5).

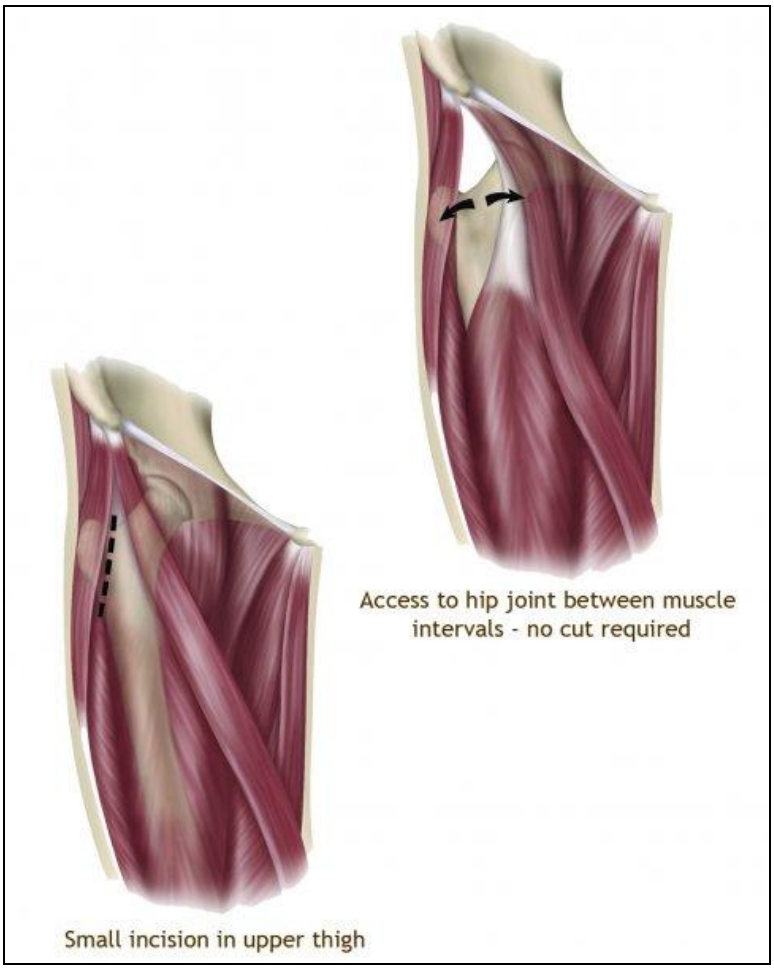


Fig 5: The interval between the rectus femoris and tensor fascia latae (figure reproduced from http://a6.sphotos.ak.fbcdn.net/).

The anterior capsule can then be visualized by placing a cobra retractor over the anterior acetabular rim. Next, the capsule is incised transversely, and the femoral head is visualized. The femoral head is dislocated, and an oscillating saw is used to transect the head, which is

then removed with a corkscrew and hip skid. After the removal of the head, a complete capsulotomy is performed, and visualization of the acetabulum is maximized by the insertion of Homan retractors anteromedially and posterolaterally.

6.2 Lateral approach (Hardinge)

The direct lateral approach, initially described by Kocher, has been subsequently modified by Hardinge (1982) and Mullikan et al. (1998) [22, 23, 24]. This approach can be performed with the patient in supine, semilateral, or lateral decubitus position. An incision is made midline along the femoral shaft starting 5 cm proximal to the greater trochanter and ending 5–6 cm below it (Fig. 6).

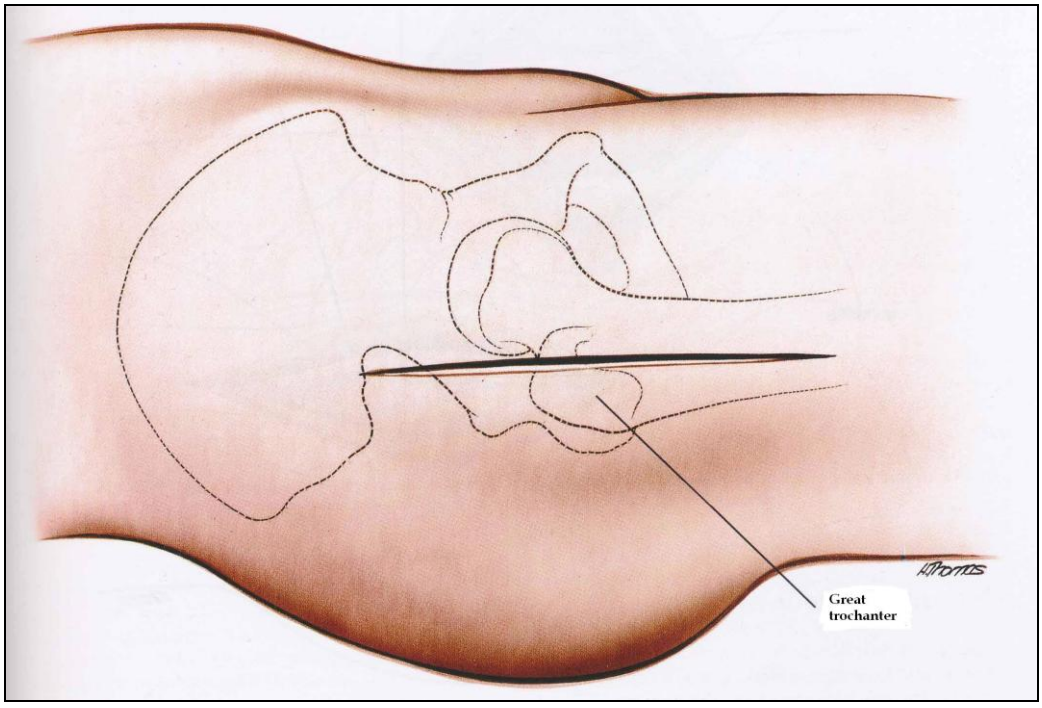


Fig. 6: Lateral approach incision (figure reproduced from www.orthopedicsurgerybook.com).

The tensor fascia latae is then exposed and incised along the entire length of the previous incision. The gluteus maximus is now exposed, and divided along its aponeurosis. Next, the sciatic nerve should be protected by the insertion of a Charnley retractor. The greater trochanter can now be visualized. The anterior one-third of the gluteus medius and vastus lateralis insertions on the greater trochanter are split longitudinally and sharply separated from the greater trochanter. The underlying gluteus minimus tendon can then be exposed and detached from the anterior greater trochanter. An anterior flap is made using the anterior portion of the gluteus medius, the underlying gluteus minimus, and the anterior portion of the vastus lateralis (Fig. 7, 8). There is no true internervous plane, and the dissection involves splitting the gluteus medius and vastus lateralis muscles (multiple modifications to the technique describe variations of this split). Division of the gluteus medius is limited to 5 cm proximal to the greater trochanter or 4 cm proximal to the superior acetabulum, as further extension places the superior gluteal neurovascular bundle at risk for injury. The capsule is now exposed and a T-shaped capsulotomy is performed. The femoral neck can then be osteotomized and removed. Exposure is optimized by placing retractors circumferentially. There are several structures that are vulnerable to retractor placement anteriorly. These include the femoral nerve, artery and vein. The lateral femoral circumflex artery may also be injured during vastus lateralis mobilization.

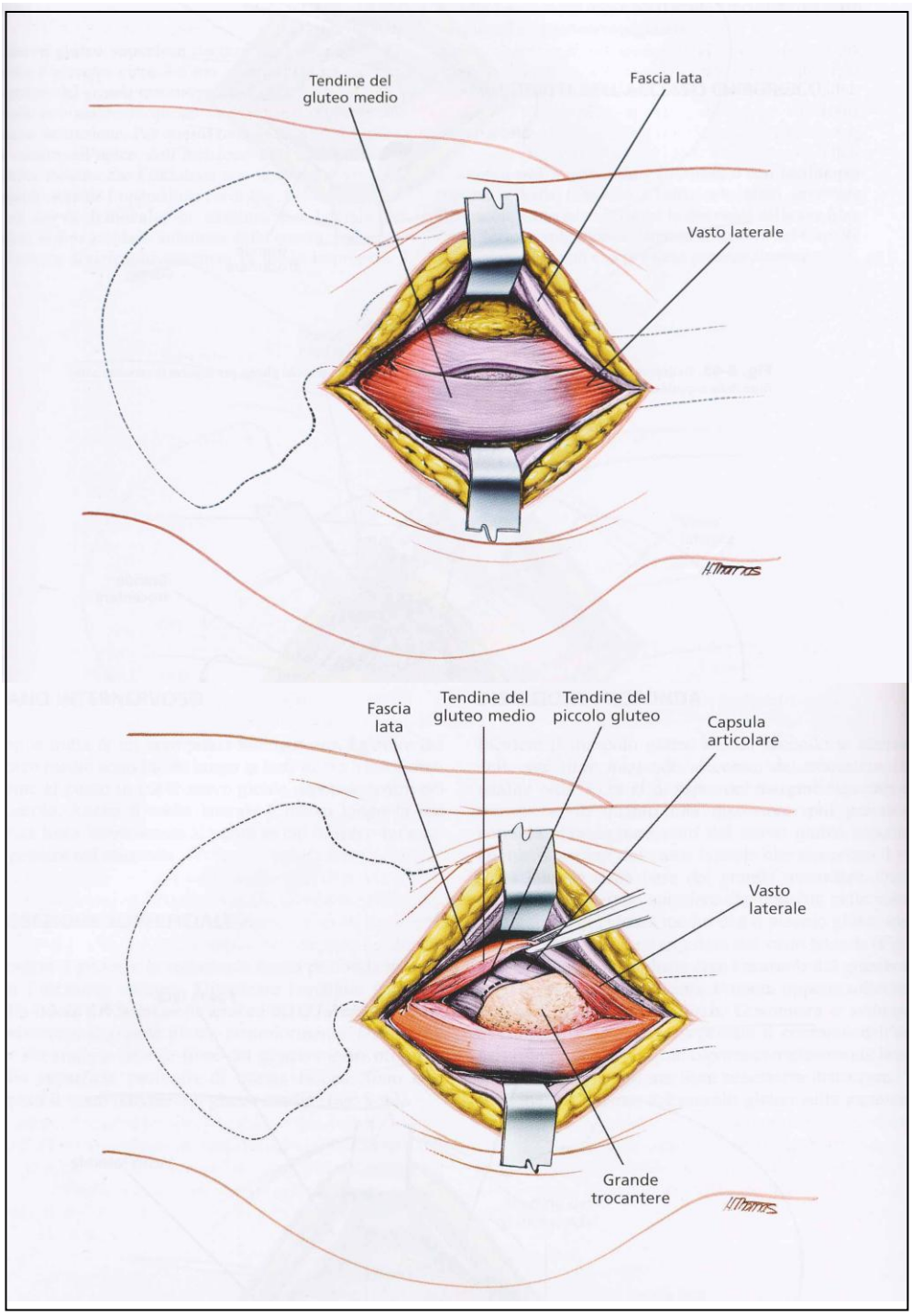


Fig. 7, 8: The anterior one-third of the gluteus medius and vastus lateralis insertions on the greater trochanter are split longitudinally and sharply separated from the greater trochanter (figures reproduced from the book “Vie di accesso ed anatomia chirurgica in ortopedia”, authors: Hoppenfeld S., ed. Verduci).

6.3 Posterolateral approach (Gibson)

The patient is placed in a lateral position, and the pelvis is secured in a neutral position (Fig. 9). After skin preparation and draping, the trochanter is outlined superiorly, inferiorly, anteriorly and posteriorly.

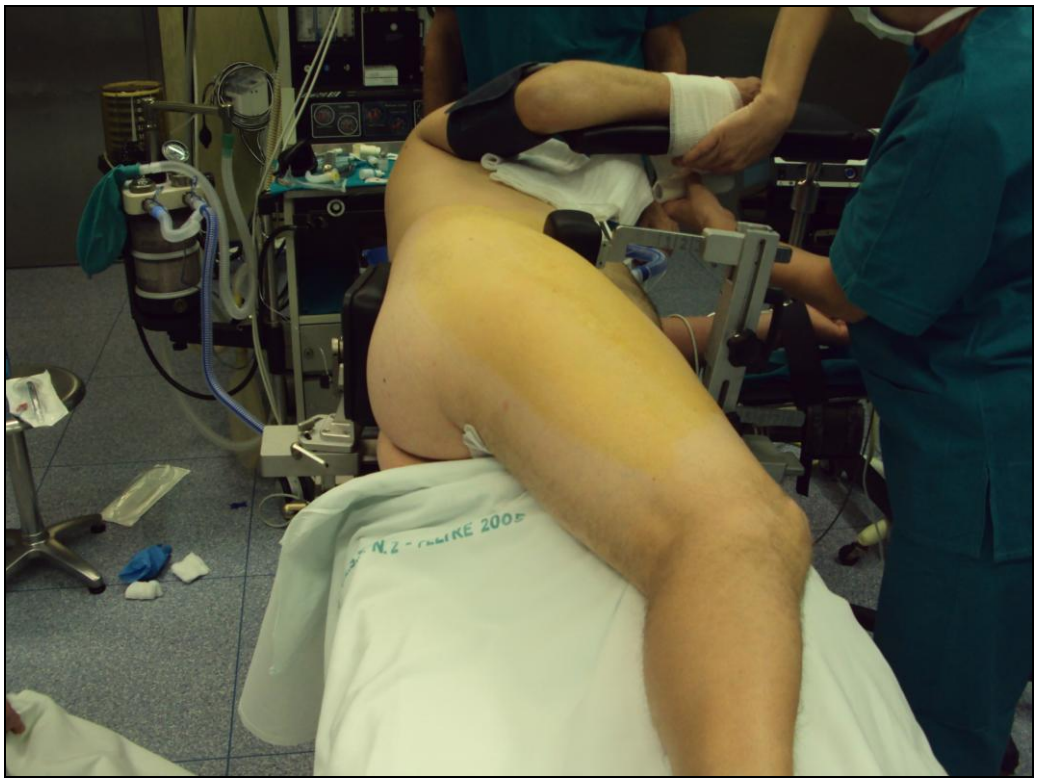


Fig.9: Posterolateral approach: the patient is placed in a lateral position, and the pelvis is secured in a neutral position (original photo).

The incision is then made longitudinally one-third over the trochanter, one-third below it, with a curved portion above the trochanter in the direction of the fibres of the gluteus maximus. The tensor fascia latae and gluteal fascia are incised in line with the skin incision. The gluteus maximus is then bluntly divided, and the superior half of the gluteal sling is divided by electrocautery. The posterior border of the gluteus medius is retracted using a 90° angle narrow Homan retractor. An Aufranc

retractor is then used superficially to the external rotators, to lie under the femoral neck. The piriformis, gemeli, and obturator externus tendons are identified and tagged with nonabsorbable braided sutures, and their insertion is released. These muscles are then positioned posteriorly to form a protective sling around the sciatic nerve (Fig. 10, 11). The gluteus minimus is divided from the capsule with a periosteal elevator, and a narrow bent Homan retractor is inserted to protect the abductor muscles. A trapezoidal posterior capsule flap is then created by incising the capsule along the longitudinal posterior border of the trochanter (Fig 10, 11). A superior incision is made along the normal course of the piriformis tendon from the greater trochanter to the acetabular labrum. An inferior incision is made along the superior border of the quadratus femoris, making sure to avoid the sciatic nerve. The corners of the capsular flap are then tagged with sutures and retracted with the short external rotators. The femoral head is dislocated with traction and internal rotation of the leg. After dislocation, the quadratus femoris is identified, and electrocautery is used to divide the muscle 2–3 mm from its insertion on the femur, preserving some tissue for later repair. Some branches of the medial femoral circumflex artery will be encountered, and these should be ligated. An Aufranc retractor is then placed on the inferior border of the lesser trochanter. The femoral neck is osteotomized, and the exposure is complete after retractors are placed anteriorly and posteriorly. Care should be taken during anterior acetabular retractor placement to avoid injuring the femoral nerve.

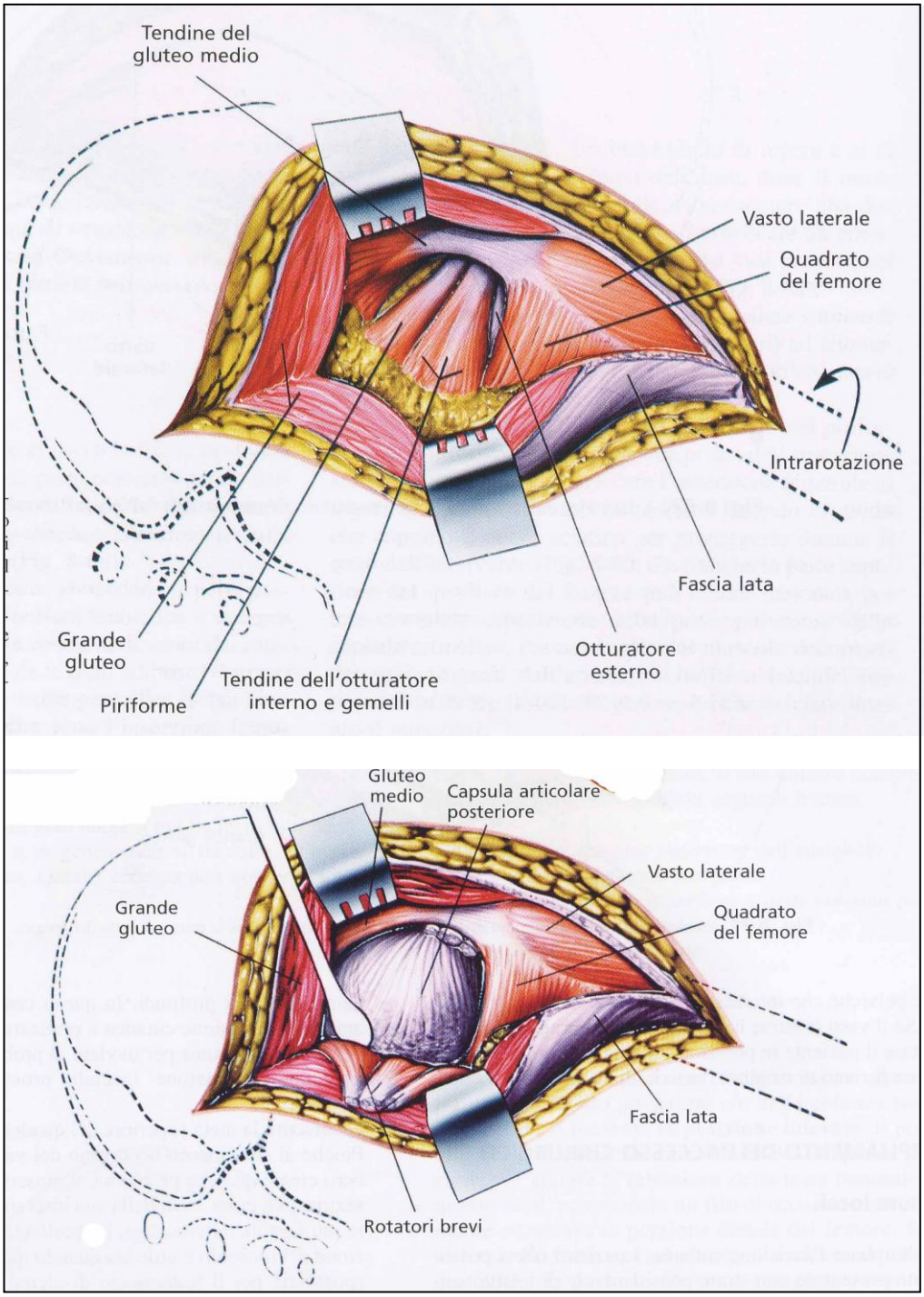


Fig. 10, 11: The piriformis, gemeli, and obturator externus tendons are identified and tagged with nonabsorbable braided sutures, and their insertion is released (figures reproduced from the book "Vie di accesso ed anatomia chirurgica in ortopedia", authors: Hoppenfeld S., ed. Verduci)

Aims of the PhD project

The goal of the current study was to examine the null hypothesis that there is no difference between the anterior, lateral and posterolateral approaches to hip arthroplasty when assessing three independent key variables, namely the functional outcome together with dislocation and revision rate, at up to 24 months' follow-up. In particular, this study was targeted at evaluating short-term follow-up results in hip arthroplasty patients treated with three different surgical techniques.

Materials and methods

Informed consent was obtained from all patients prior to the inclusion in the study. As this study was a standard of care assessment, local ethics committee authorization was not required. The study was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki as revised in 2000. Between July 2009 and October 2011, at the Department of Orthopedics and Traumatology of the Santa Maria del Prato Hospital in Feltre (Belluno-Italy), hip arthroplasty was performed for 90 patients using three different surgical approaches: anterior (Group A), direct lateral (Group B) and posterolateral approach (Group C). Group A consisted of 30 patients (13 males and 17 females), with a mean age of 67 years (range 58-74), and an average Body Mass Index of 28.3 (range 23-35). Group B consisted of 30 patients (13 males and 17 females), with a mean age of 68 years (range 59-75) and an average Body Mass Index of 27.9 (range 20-34). Group C consisted of 30 patients (11 males and 19 females), with a mean age of 68 years (range 56-75) and an average Body Mass Index of 22.6 (range 21.5-26.5). Inclusion criteria were: aged between 55 and 75 years; primary OA of the hip diagnosed according to the clinical and radiological criteria of the American College of Rheumatology (ACR); disease severity grade 2–3 based on the Kellgren–Lawrence radiographic system [25]; persistent hip pain from at least four months; and a visual analogue scale (VAS) pain index of at least 4 cm while walking. Participants were required to have no significant laboratory abnormalities. Exclusion criteria were the presence of another rheumatic condition leading to secondary OA (such as rheumatoid arthritis or calcium

pyrophosphate dihydrate deposition disease), serious progressive medical conditions (such as cancer, AIDS, end-stage renal disease, cardiac disease or neurological disease), or breastfeeding. Patients were also excluded if they were currently being treated, or had been treated within three months prior to inclusion with corticosteroids or indomethacin; patients who had been treated within six months preceding inclusion with intra-articular viscosupplements were also excluded. An identical hip prosthesis was implanted in all patients: a CLS (fig. 12) cementless femoral stem (Zimmer^{R}) with a ceramic femoral head (Fig. 12), and ALLOFIT cementless acetabular cup (Zimmer^{R}) with a polyethylene liner (Fig.12). All procedures were performed by the same expert surgeon and the choice of surgical approach in a given patient was random.

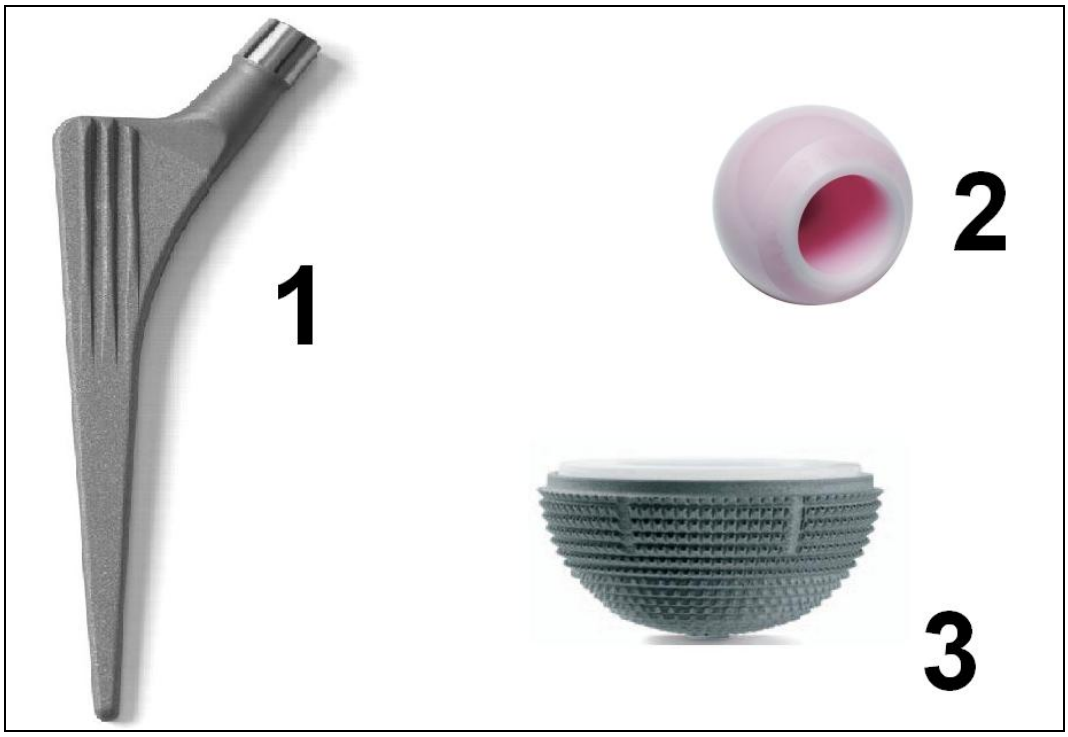


Fig. 12: 1) CLS cementless stem, 2) ceramic femoral head; 3) ALLOFIT cup with polyethylene liner.

The same pre- and postoperative protocol was used for all groups. All patients underwent surgery with epidural anesthesia, upon deposit of two units of autologous blood. Mechanical foot pumps and pharmacological antithrombotic prophylaxes were used. Patients received antibiotics for 72 h postoperatively. The drain was removed on the second postoperative morning by a resident physician. No specific protocol was used to measure drain output. On the first postoperative day, patients were switched to a standardized multimodal analgesic protocol, which did not involve parenteral narcotics. Functional rehabilitation began on the second postoperative day for all patients. Patients were transferred to the Rehabilitation Unit at the Lamon Hospital after six days (+/- two days), and received the same standardized rehabilitation treatment. Mean length of inpatient stay was four weeks (+/- one week). During the hospital stay, all patients received a 60 minute physiotherapy session once a day. The main goals of the rehabilitation were to improve range of motion, muscle strength, aerobic capacity and reintroduce normal daily activities. During the first two weeks treatment focused on individual limitations (range of motion of the affected joints, strength and aerobic capacity). During the third week, the training was focused on restoration of functional abilities such as walking, climbing stairs, standing up from a chair and cycling. Patients were encouraged to walk without assistive devices as soon as possible. The three groups were compared in terms of patients' mean age, sex, body weight and ASA class. The assessment also included the following parameters: surgery duration, intraoperative complications, intra-

and postoperative blood loss, postoperative pain, length of stay and type of discharge.

Clinical follow-up was performed at 1, 6, 12 and 24 months from the initial surgery (baseline). All evaluations were performed by a physician who was unaware of the surgical approach used. Data on the following outcome elements were extracted: pain, function, overall health status, complications and joint crepitus (noise). The level of hip pain was assessed using the visual analogue scale (VAS) from 0 to 10 cm. Specific data on hip joint function (using the Harris Hip Score (HHS) [26] and the WOMAC index [27]) were gathered during pre- and postoperative clinical check-ups. The HHS (Tab. 6) is based on a total of 100 possible points; each question of the assessment is awarded a certain number of points based on how it is answered. The questions are grouped into the following categories: pain, function, functional activities and physical examination findings. The HHS results are classified as follows: 90-100 as an excellent score, 80-90 as good, 70-79 as fair, 60-69 as poor and below 60 as a failed result. The Western Ontario and McMaster Universities (WOMAC) index consists of 24 questions (with five of them regarding pain, two stiffness and 17 physical function) and can be completed in less than five minutes (Tab. 7). The WOMAC index is a valid, reliable and sensitive instrument for the detection of clinically important changes in health status following a variety of interventions (including pharmacologic or surgical interventions, physiotherapy etc.). Individual question responses are assigned a score between 0 (extreme) and 4 (None). Question scores are then summed to form a raw score ranging from 0 (worst) to 96 (best).

Finally, the raw scores are normalized by multiplying each score by 100/96. This produces the final WOMAC Score between 0 (worst) and 100 (best).

Harris Hip Score

Hip ID:

Study Hip: ☐ Left ☐ Right

Examination Date (MM/DD/YY): / /

Subject Initials: | | | |

Medical Record Number:

Interval: _____

Harris Hip Score

Pain *(check one)*

- ☐ None or ignores it (44)
- ☐ Slight, occasional, no compromise in activities (40)
- ☐ Mild pain, no effect on average activities, rarely moderate pain with unusual activity; may take aspirin (30)
- ☐ Moderate Pain, tolerable but makes concession to pain. Some limitation of ordinary activity or work. May require Occasional pain medication stronger than aspirin (20)
- ☐ Marked pain, serious limitation of activities (10)
- ☐ Totally disabled, crippled, pain in bed, bedridden (0)

Limp

- ☐ None (11)
- ☐ Slight (8)
- ☐ Moderate (5)
- ☐ Severe (0)

Support

- ☐ None (11)
- ☐ Cane for long walks (7)
- ☐ Cane most of time (5)
- ☐ One crutch (3)
- ☐ Two canes (2)
- ☐ Two crutches or not able to walk (0)

Distance Walked

- ☐ Unlimited (11)
- ☐ Six blocks (8)
- ☐ Two or three blocks (5)
- ☐ Indoors only (2)
- ☐ Bed and chair only (0)

Sitting

- ☐ Comfortably in ordinary chair for one hour (5)
- ☐ On a high chair for 30 minutes (3)
- ☐ Unable to sit comfortably in any chair (0)

Enter public transportation

- ☐ Yes (1)
- ☐ No (0)

Stairs

- ☐ Normally without using a railing (4)
- ☐ Normally using a railing (2)
- ☐ In any manner (1)
- ☐ Unable to do stairs (0)

Put on Shoes and Socks

- ☐ With ease (4)
- ☐ With difficulty (2)
- ☐ Unable (0)

Absence of Deformity (All yes = 4; Less than 4 =0)

- Less than 30° fixed flexion contracture ☐ Yes ☐ No
- Less than 10° fixed abduction ☐ Yes ☐ No
- Less than 10° fixed internal rotation in extension ☐ Yes ☐ No
- Limb length discrepancy less than 3.2 cm ☐ Yes ☐ No

Range of Motion (*Indicates normal)

- Flexion (*140°) _____
- Abduction (*40°) _____
- Adduction (*40°) _____
- External Rotation (*40°) _____
- Internal Rotation (*40°) _____

Range of Motion Scale

211° - 300° (5)	61° - 100 (2)
161° - 210° (4)	31° - 60° (1)
101° - 160° (3)	0° - 30° (0)

Range of Motion Score _____

Total Harris Hip Score _____

Tab. 6: Harris Hip Score

WOMAC OSTEOARTHRITIS INDEX

1. The following questions concern the amount of pain you are currently experiencing in your knees. For each situation, please enter the amount of pain you have experienced in the past 48 hours.

		None	mild	moderate	severe	extreme
A. Walking on a flat surface	A.	☐	☐	☐	☐	☐
B. Going up or down stairs	B.	☐	☐	☐	☐	☐
C. At night while in bed	C.	☐	☐	☐	☐	☐
D. Sitting or lying	D.	☐	☐	☐	☐	☐
E. Standing upright	E.	☐	☐	☐	☐	☐

2. Please describe the level of pain you have experienced in the past 48 hours for each one of your knees.

		None	mild	moderate	severe	extreme
A. Right knee	A.	☐	☐	☐	☐	☐
B. Left knee	B.	☐	☐	☐	☐	☐

3. How severe is your stiffness after first awakening in the morning?

None	mild	moderate	severe	extreme
☐	☐	☐	☐	☐

4. How severe is your stiffness after sitting, lying, or resting later in the day?

None	mild	moderate	severe	extreme
☐	☐	☐	☐	☐

5. The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities, please indicate the degree of difficulty you have experienced in the last 48 hours, in your knees.

What degree of difficulty do you have with:

		None	mild	moderate	severe	extreme
A. Descending (going down) stairs	A.	☐	☐	☐	☐	☐
B. Ascending (going up) stairs	B.	☐	☐	☐	☐	☐
C. Rising from sitting	C.	☐	☐	☐	☐	☐
D. Standing	D.	☐	☐	☐	☐	☐
E. Bending to floor	E.	☐	☐	☐	☐	☐
F. Walking on a flat surface	F.	☐	☐	☐	☐	☐
G. Getting in/out of car	G.	☐	☐	☐	☐	☐
H. Going shopping	H.	☐	☐	☐	☐	☐
I. Putting on socks/stockings	I.	☐	☐	☐	☐	☐
J. Rising from bed	J.	☐	☐	☐	☐	☐
K. Taking off socks/stockings	K.	☐	☐	☐	☐	☐
L. Lying in bed	L.	☐	☐	☐	☐	☐
M. Getting in/out of bath	M.	☐	☐	☐	☐	☐
N. Sitting	N.	☐	☐	☐	☐	☐
O. Getting on/off toile	O.	☐	☐	☐	☐	☐
P. Heavy domestic duties (mowing the lawn, lifting heavy grocery bags)	P.	☐	☐	☐	☐	☐
Q. Light domestic duties (such as tidying a room, dusting, cooking)	Q.	☐	☐	☐	☐	☐

Tab. 7: WOMAC index

A table (Tab. 8) was created for each patient, on which to record data on joint function, HHS, WOMAC and VAS scores at each clinical control point.

	Pre-surgery	1 month	3 months	6 months	12 months	24 months
Flexion						
Extension						
Abduction						
Adduction						
External rotation						
Internal rotation						
Womac						
H.H.S.						
V.A.S.						

Tab.8: Table created to collate the study data for each individual patient.

Total blood loss was calculated using a mathematic formula developed by Rosencher et al [28], which takes into account the patient's pre- and postoperative weight, height and hematocrit levels, as well as any autologous or homologous blood transfusions performed intra- and/or postoperatively (Tab. 9).

Total blood loss (mL) = [*Total RBC loss* (mL)]/0,35

Total RGB loss (mL) = [*Uncompensated RBC loss* (mL)] + [*Compensated RBC loss* (mL)]

Uncompensated RBC loss (mL) = [*Initial RBC* (mL)] – [*Final RBC* (mL)]

Compensated RBC loss = [Sum of RBCs received from the various source of transfusion]

Initial RBC (mL) = [*Estimated blood Volume* (mL)] x [Initial Hct level (%)] at Day -1

Final RBC (mL) = [*Estimated blood volume* (mL)] x [Final Hct level (%)] at Day + 3

Estimated blood volume (mL) = Women: [*Body surface area* (m^2)] x 2430; Men: [*Body surface area* (m^2)] x 2530

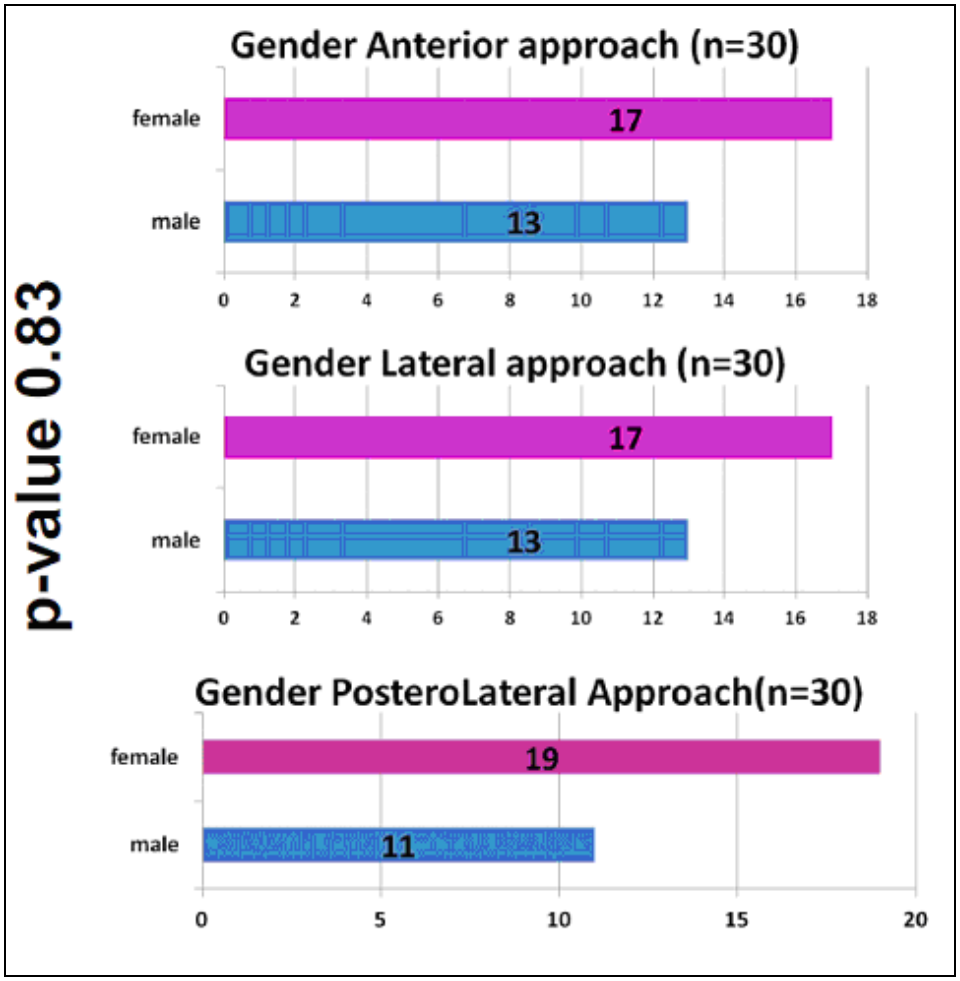
Body surface area (m^2) = 0,0235 x [height (cm)] 0,42246 x [weight (kg)] 0,52456

Tab.9: Rosercher's formula

Statistical analysis was performed using Anova Informatic statistical tests, considering the value of $p<0.05$ statistically significant.

Results

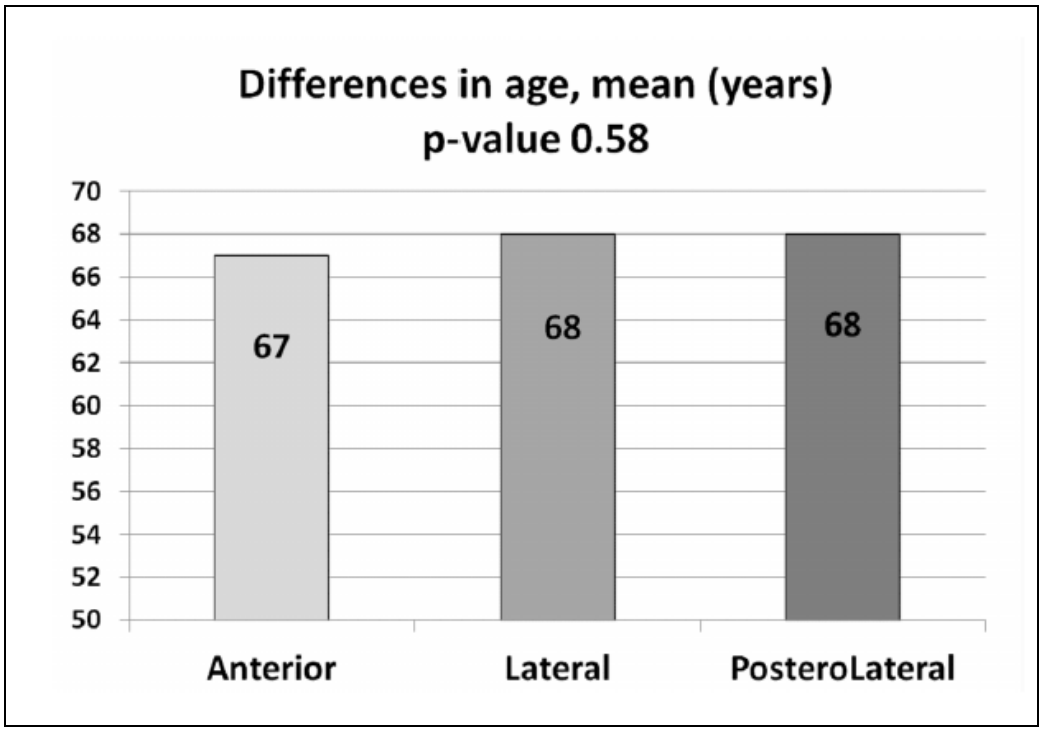
The three groups were similar in mean age (Tab. 10), weight, sex (Tab. 11) and ASA status.



Tab.10: Number of male and female patients in the three groups

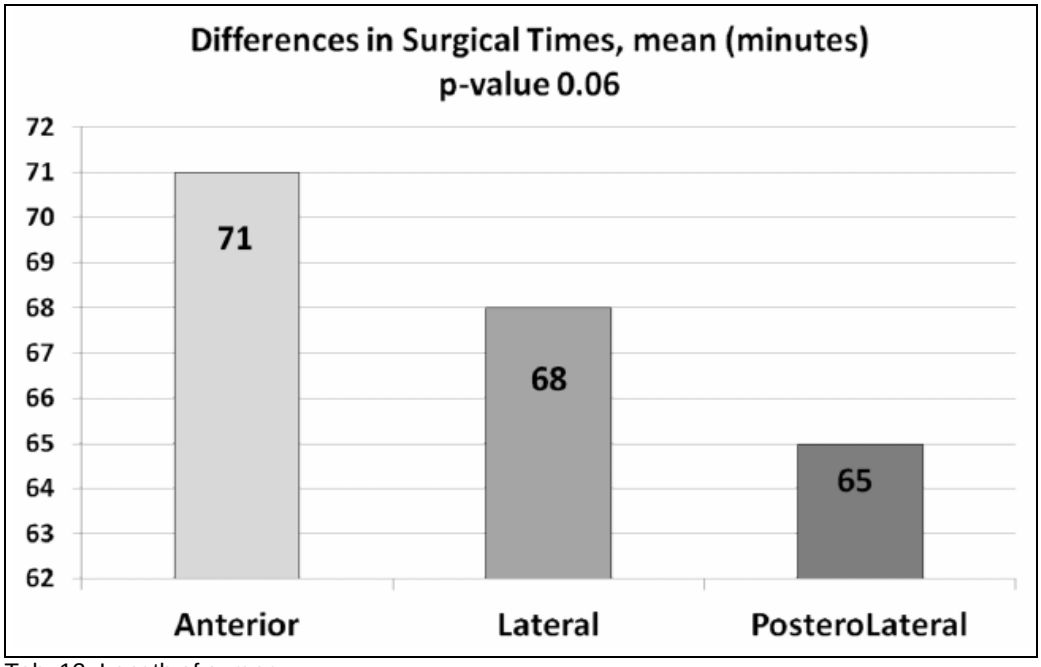
The BMI was not significantly different between the groups. The A group had an average BMI of 27.0, compared to the B group with an average of 27.2, and to the C group with an average of 26.6. The mean surgery

duration resulted significantly longer in the direct anterior approach group, lasting an average of seven minutes longer than the posterolateral procedure.



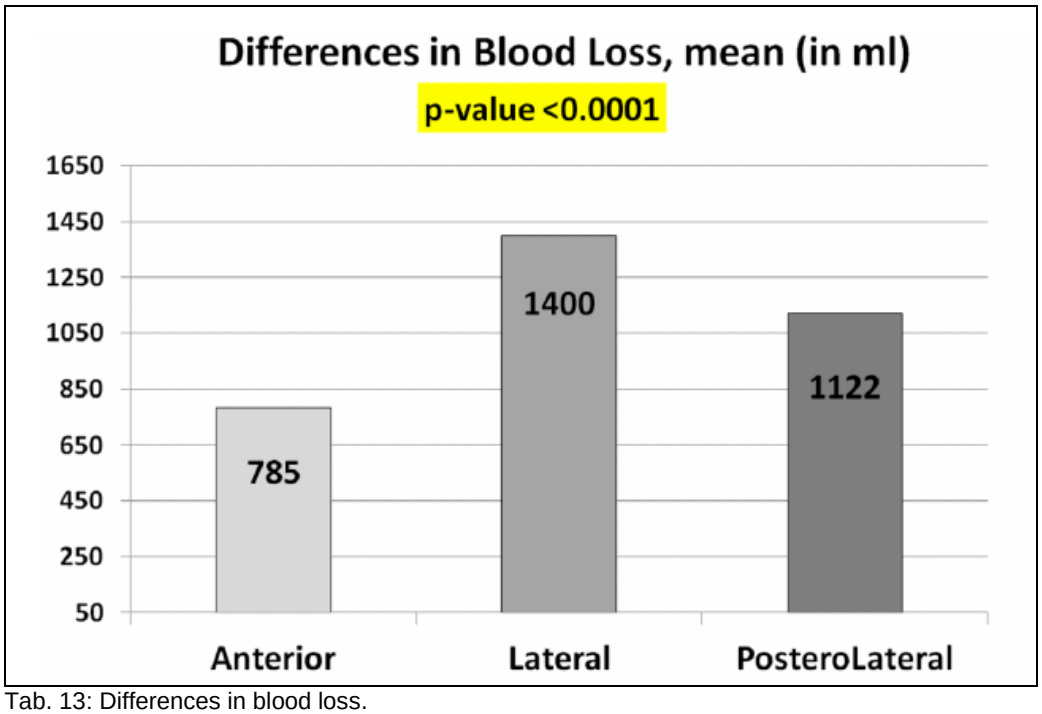
Tab. 11: Differences in the mean age of the groups.

The anterior approach had a minimum surgery duration of 60 minutes and a maximum duration of 135 minutes. The average surgery duration in this group was 71 minutes. The average surgery duration for the lateral approach group was 68 minutes. The individual length of the surgeries varied greatly in this group, with a minimum duration of 61 minutes and a maximum of 125 minutes. The posterolateral approach had a minimum surgery duration of 60 minutes and a maximum of 135 minutes. The average length of surgery in this group was 65 minutes (Tab. 12).



Tab. 12: Length of surgery.

Spinal anaesthesia was administered to all patients. The fluid volumes infused during the different procedures resulted significantly different. Infusions of crystalloids, colloids and postoperative administration of autologous and homologous packed red blood cells were significantly higher in patients treated with the lateral approach (43%, vs. 40% for the posterolateral approach, vs. 28% for the anterior approach). Haemoglobin values were recorded on the first and third postoperative day, and compared with the preoperative values. Hb values were significantly higher in patients treated with the direct anterior approach (12.3 g/dl, vs. 10.1 g/dl for the posterolateral approach, vs. 9.6 for the lateral approach). Blood loss was higher in the B group (Tab. 13).



Tab. 13: Differences in blood loss.

Intraoperative complications included a greater trochanteric fracture in one patient from the A group, and two intensive care unit admissions (one in the B group and one in the C group) for cardiocirculatory complications. Patients were transferred to the regular ward on the day of surgery, or on the first postoperative day. Other complications detected (Tab. 14) included dislocation of the hip prosthesis that was prevalent in the C group, and femoral cutaneous nerve palsy that was prevalent in the B group. Postoperative nerve dysfunction resulted common in the A group with three affected patients, and in the B group, four patients reported postoperative paraesthesia over the lateral femoral region because of damage to the lateral femoral cutaneous nerve. Patients in the C group did

not present any nerve dysfunction whatsoever. This difference is statistically significant (p=0.013). The frequency of postoperative hip dislocation was 6.6% in the C group and 3.3% in the A group. The three hip dislocations in the A and C groups could not be successfully treated with only repositioning. All cases of haematoma in the different groups were treated by incision and drainage. The fracture of the greater trochanter in the A group did not require changes in the surgical procedure, nor any surgical treatment.

Complications	Anterior approach (Group A)	Lateral approach (Group B)	Postero-lateral approach (Group C)
Dislocation of hip prosthesis	1	0	2
Greater trochanteric fracture	1	0	0
Sciatic nerve palsy	1	0	2
Femoral cutaneous nerve palsy	3	4	0
Tensor fascia latae muscle rupture	2	0	0
Cardiocirculatory complications	0	1	1
Haematoma	2	3	2
Infections	0	0	0
Fracture of the femur after direct trauma	0	2	1

Table 14. Complications detected.

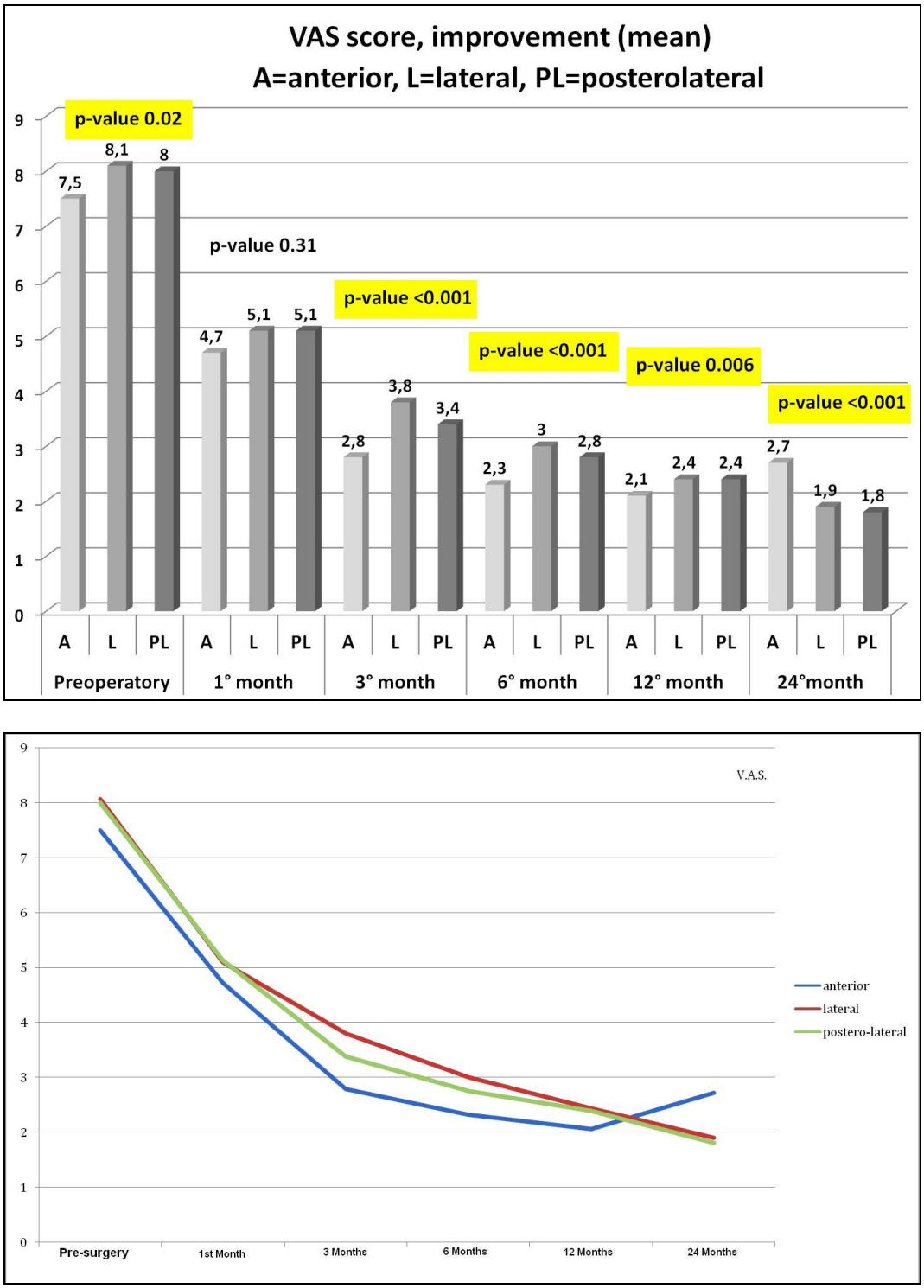
The VAS, HHS and WOMAC scales were used to assess the results obtained during the follow-up period.

The pain levels detected by the VAS assessment were significantly lower in patients treated with the anterior approach at every follow-up point, reaching a high significance at the 3- ($p<0,001$), 6- ($p<0,001$) and 12-month ($p<0,006$) follow-up points. However, at the 12- and 24-month follow-up points, the VAS assessment highlighted the development of a persistent groin pain with prolonged walking in some patients treated with this surgical approach (Tab. 15, 16).

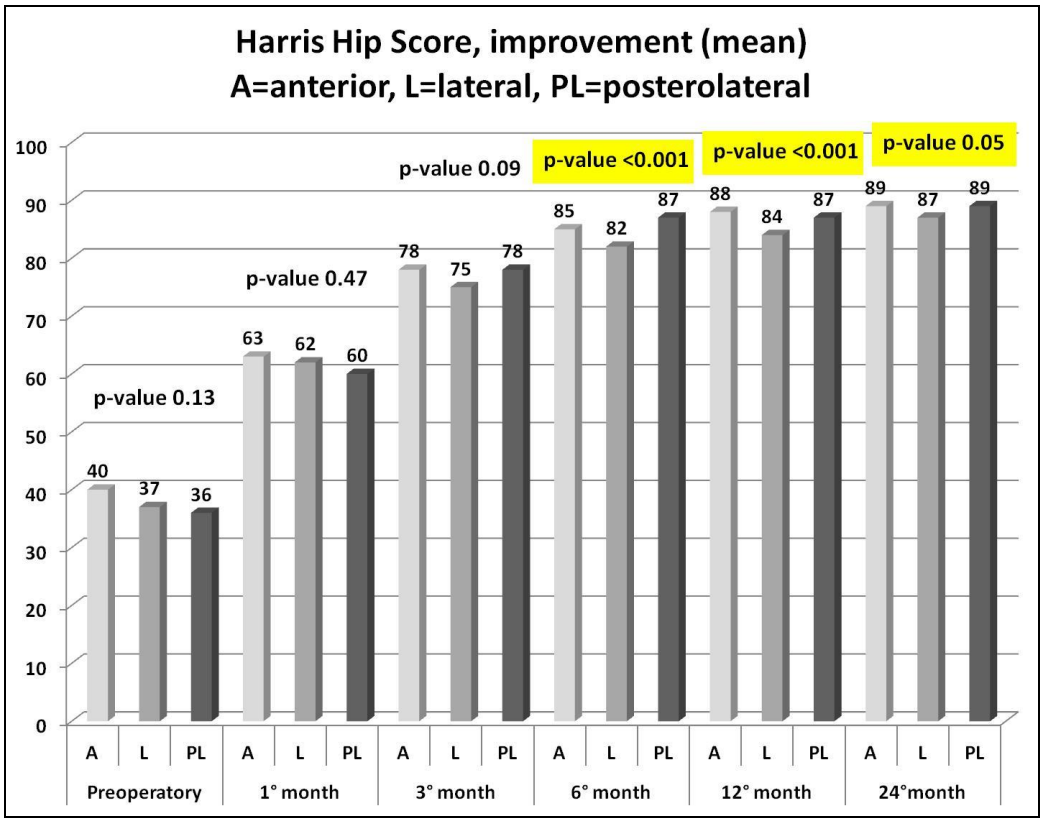
The HHS values resulted statistically significant in the posterolateral approach group at the 6- ($p<0,001$) and 12-month ($p<0,001$) follow-up points. The line chart shows the superposition of the results for the first three months, the subsequent divergence from 6 to 12 months, and the reoccurring overlap after the 12-month point (Tab. 17, 18).

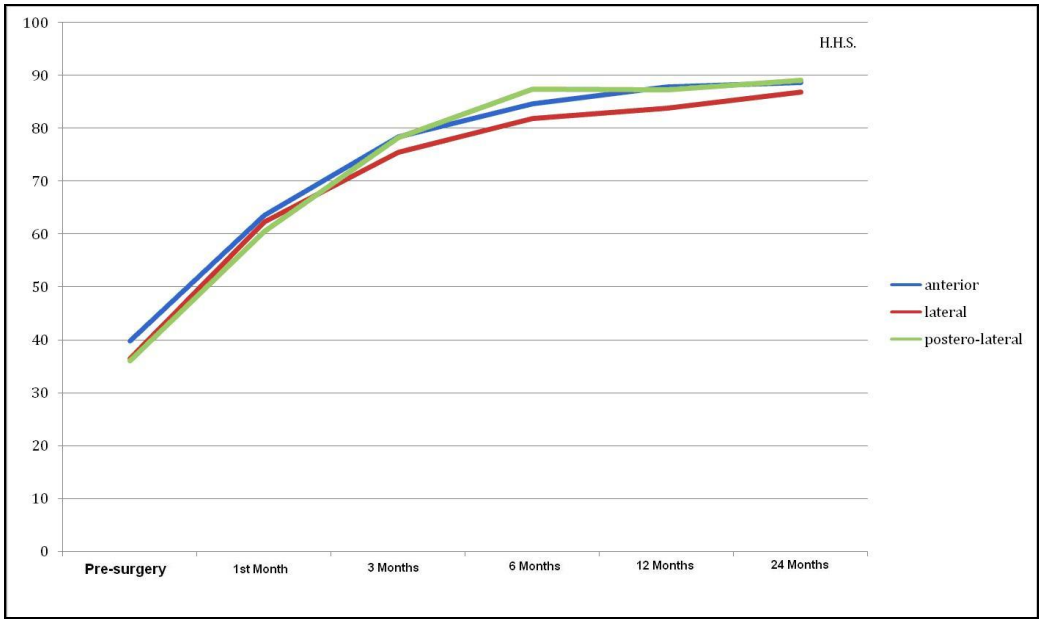
The results of the WOMAC assessment highlight the statistical significance of results obtained in the anterior approach group at the 1- ($p <0.007$) and 3-month ($p <0.021$) follow-up points only (Tab. 19, 20).

The quality and quantity assessment of the range of motion of the prosthesis highlights a greater mechanical excursion in patients treated with the posterolateral approach, in particular on flexion (Tab. 21) and external rotation (Tab. 22).

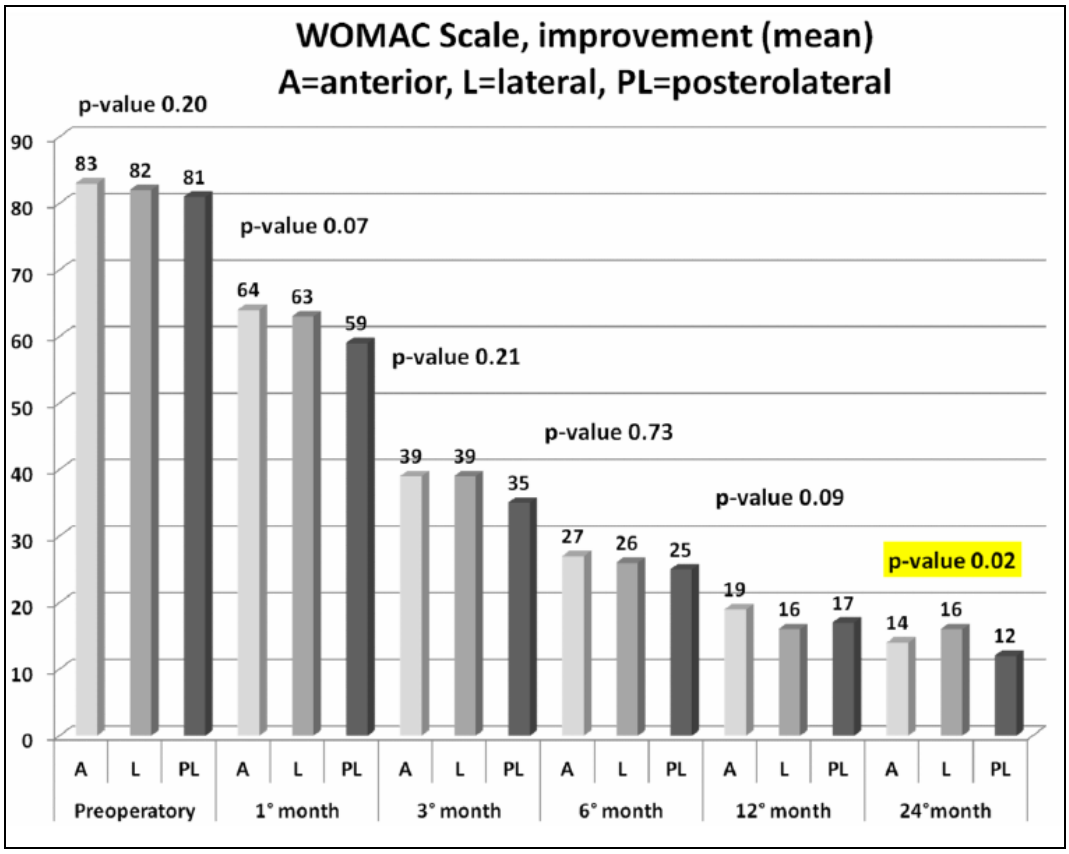


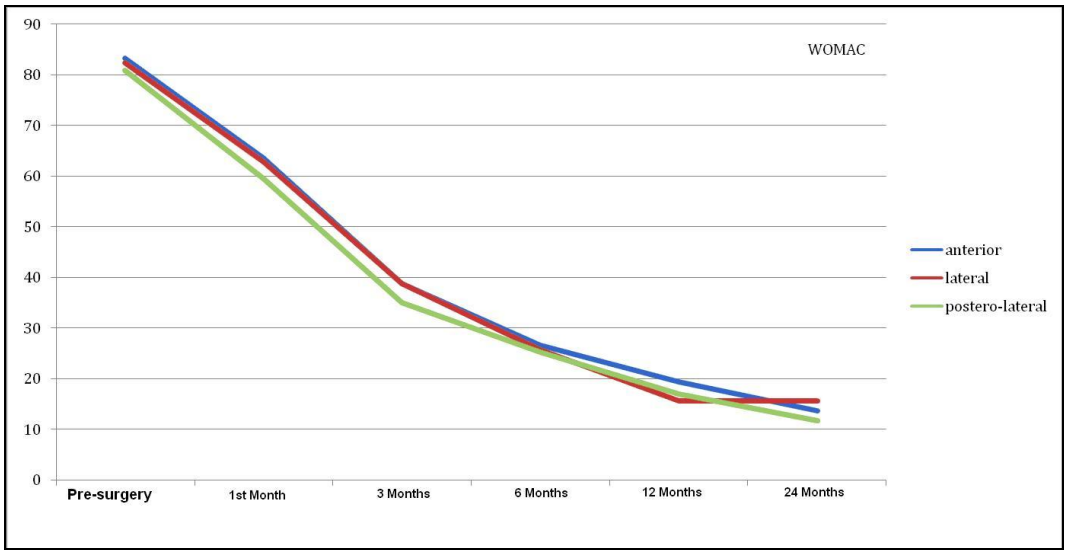
Tab. 15, 16: Results of the VAS assessment during the 24 months of follow-up.





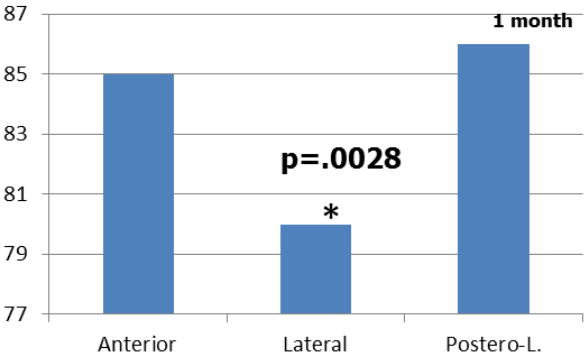
Tab. 17, 18: Results of the Harris Hip Score during the 24 months of follow-up.

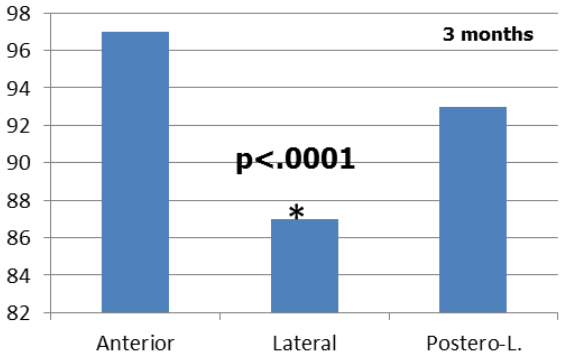


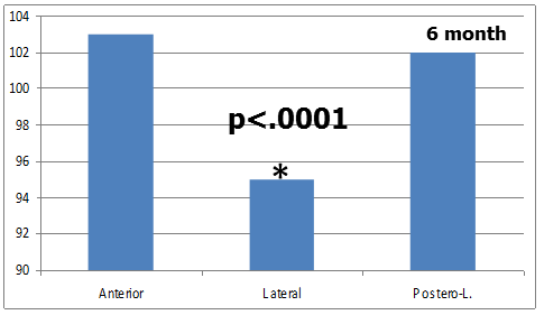


Tab. 19, 20: Results of the WOMAC assessment during the 24 months of follow-up.

Table 21: The flexion of the hip prosthesis improved in all 3 groups. Statistically significant is the quality of the articular range of motion in patients treated with posterolateral and anterior approach at the 1-, 3- and 6-month follow-up points.







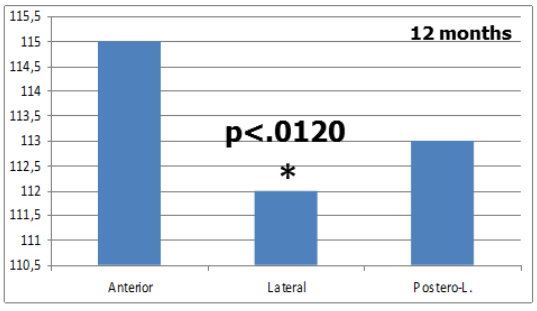
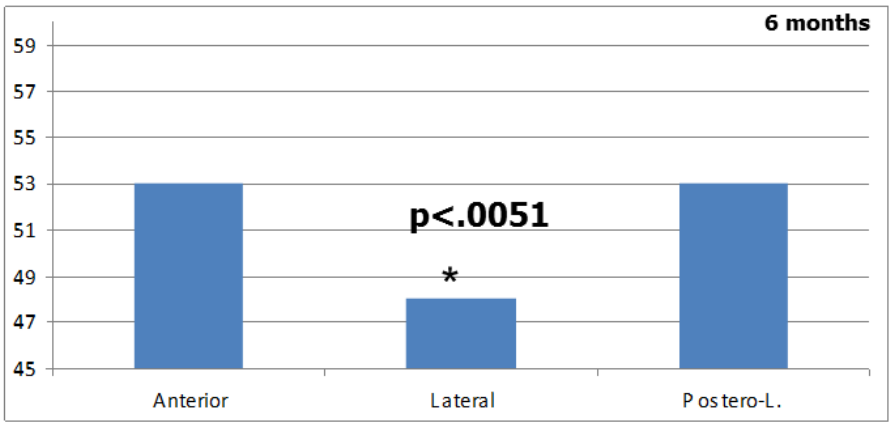
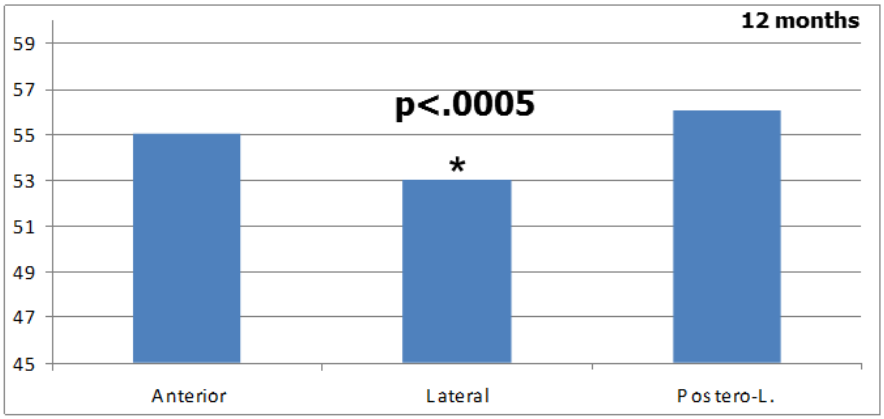
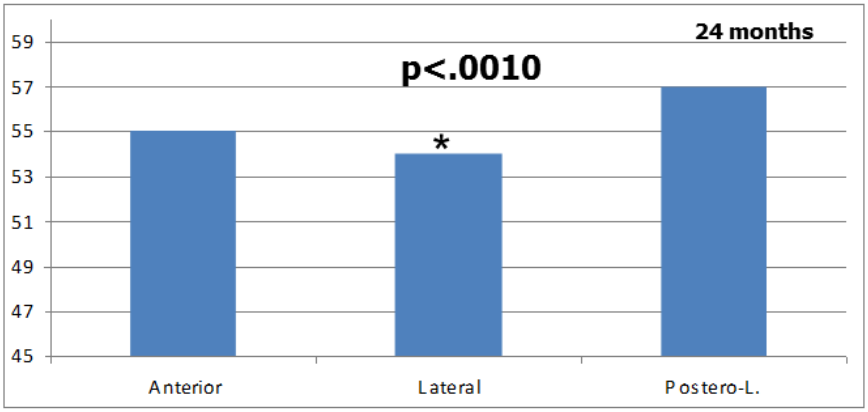


Table 22: The external rotation of the hip prosthesis improved in all 3 groups. Statistically significant is the quality of the articular range of motion in patients treated with posterolateral approach at the 6-, 12- and 24-month follow-up points.







Discussion

In a THA, both the femur and the acetabulum are replaced with implant prostheses. Specifically, a metal stem is inserted into the thighbone. Attached to the neck of the stem is a hip ball just over an inch in diameter, that fits into a liner. Together, the ball and liner create the new joint. The liner is inserted into a metal shell that in turn is anchored to the pelvis. There are a number of different surgical approaches that can be employed, depending on the individual situation of each patient. The hip joint can be approached from the front of the hip (anterior approach), from the back (posterolateral approach), from the side (lateral approach), or from midway between front and side (anterolateral approach). The question regarding which surgical approach is best has been extensively debated. Despite this, no consensus has been reached regarding which approach is ideal for primary THA. The advantages and disadvantages of each approach have been well documented and the choice of which approach to use has largely depended on surgeon preference, which in turn is a reflection of the surgeon's training and experience. This thesis assesses the effect of three common surgical approaches on functional outcomes, dislocation rate, and revision rate, as objective measures of success after primary THA. The three groups were similar in terms of sex, age and weight. After two years of follow-up, complete data had been collected for all patients (90). Most previous studies have not assessed long-term results, with only one study that evaluated the five-year clinical outcome of patients [29]. The follow-up period was short, but covered the critical period during which the benefits of the minimally invasive approach

to THA are supposed to be maximal. Flören et al. found that the THA technique did not compromise the long-term clinical and radiographic findings when compared with conventional techniques [30]. Studies in the literature about the clinical benefits of minimally invasive surgical techniques, report insufficient or non-uniform case studies in the selection of patients and results reported. In this study, the patients in each group were uniform in age and all aspects of the disease. For a hip replacement procedure to be truly “minimally invasive”, it is not indispensable to perform the operation through the smallest possible skin incision, but it is essential that the procedure be performed with minimal soft-tissue trauma, sparing all muscle attachments. Of course, the skin incision performed for the anterior surgical approach is smaller (about 2 cm less) than that used during the direct lateral or posterolateral approaches. The minimal invasiveness of the surgical incision offers a reduction of muscle tissue damage, and, consequently, a reduction in bleeding. The theoretical advantages of the anterior mini-incision include a good view of the acetabulum, while preserving all muscles; additionally, fluoroscopy is not required, and one does not have to use a specific implant for this approach. Practical advantages include fast postoperative recovery, no limp (because the buttock muscles and the greater trochanter are not affected) and almost no risk of dislocation [31]. The posterolateral approach has the benefits of preserving abductor function [32] and providing good exposure of the proximal femur and acetabulum. The main disadvantage seems to be the reportedly higher dislocation rate compared with other approaches [33]. The lateral approach involves detachment of

the gluteus medius and minimus from the greater trochanter, with a high incidence of postoperative limp [34]. The operating table used for the lateral and posterolateral approaches is identical, and is commonly found in surgical departments. The table used for the anterior approach is specific and complex, characterized by tractions and tensioners. A disadvantage of this approach is, in fact, the need for a special operating table and specific tools. Potential complications include intraoperative femur and ankle fractures, and damage to the lateral femoral cutaneous nerve. These can be avoided by using caution during the external rotation of the hip and the lowering of the foot of the lower limb, which must be performed without traction. The hip fractures detected during the present study did not occur during the surgical procedure. In the anterior approach group, one fracture caused by direct trauma occurred one year after the initial surgery. In the posterolateral approach group, two fractures caused by direct trauma occurred one and two years after treatment respectively. The mean surgery duration was different for the three approaches: 71 minutes for the anterior approach, 68 minutes for the lateral approach and 65 minutes for the posterolateral approach (p-value: 0.06).

There is, however, some controversy in the literature concerning the accuracy of the estimated blood loss in relation to the real calculated loss, with significantly higher quantities reported in older studies compared with those in more recent studies on minimally invasive approaches [35, 36]. The methodology used for measuring intraoperative blood loss is highly variable, ranging from the use of mathematic formulae to blood parameter measurements. In agreement with the results of this thesis, Wentz et al.

[37], Goldstein et al. [38] and Chimento et al. [39] reported a statistically significant reduction of blood loss in patients treated with the anterior surgical approach. Most authors have reported lower bleeding levels when using minimally invasive surgery techniques. From an analysis of only those studies in which a comparison between the minimally invasive posterolateral approach and the traditional approach was made, it was perceived that the bleeding estimates were lower with the less invasive approach. The estimated blood loss quantities were significantly lower (ranging from 152 ml to 598 ml) than in the present sample, for which the estimated mean total blood loss in the mini-incision group was 1083.5 ml [40, 41]. In this study, the blood loss was significantly higher in patients treated with the direct lateral approach, while the posterolateral approach resulted in a degree of blood loss that was lower than that of the anterior approach, but higher than that of the lateral approach.

Therefore, the type of surgical approach influences the extent of blood loss, regardless of the size of the skin incision and surgery duration. Less blood loss results in a reduced need for blood transfusions, and this is a particular advantage in some patients; these include patients suffering from anemia, hemophilia and cachexia, as well as patients with religious restrictions, such as Jehovah's Witnesses. The incidence of major orthopedic complications was low in all groups. Greater trochanter fracture occurred in one patient in the A group. This is a typical complication of the minimally invasive anterior approach, related to an insufficient release of the capsule [42]. The fractures that occurred one and two years after surgery in the A and C groups were caused by direct trauma from

accidental fall, and, therefore, were not related in any way to the type surgical approach performed. The operative trauma associated with traction and manipulation during hip surgery may render the nerves more vulnerable. The posterolateral approach is traditionally associated with injury to the sciatic nerve [43]. The reported incidence of nerve injury after total hip arthroplasty ranges from 0.7% to 3.0% for primary surgery and 2.9% to 7.6% for revision surgery [44]. Schmalzried et al. [45] reviewed 3126 consecutive total hip replacements and found an overall 1.7% incidence of nerve injury (1.3% in primary arthroplasties). Between 80% and 90% of these nerve injuries involved the sciatic nerve, and were followed in frequency by femoral nerve injury [46] (estimated incidence of 0.1–0.4%), with isolated case reports of obturator [47] or gluteal [48] nerve injury. Possible etiologies of intraoperative injury include direct trauma, retractor pressure or traction, stretch and/or compression of the nerve secondary to leg positioning, stretch due to excessive lengthening of the extremity, and local pressure [49]. In this study, one case of complete lesion of the sciatic nerve and one case of sciatic nerve palsy occurred in group C (3%), while one case of femoral cutaneous nerve palsy was detected in group A (3%), with two similar cases occurring in group B (6%). These patients were diagnosed and treated promptly, with an immediate reversal of symptoms. Each of these patients had an uneventful postoperative period, with complete symptomatic recovery before discharge from hospital.

Dislocation of the femoral head component from the acetabular socket occurs in 1% to 3% of primary total hip arthroplasties. The main causes of

dislocation include inadequate patient compliance with postoperative precautions, and malposition of the prosthetic components at the time of the operation. Dislocation is second only to loosening as a cause of revision [50]. The most common technical error predisposing to dislocation is malposition of the acetabular component. Most dislocations occur within six months from the initial surgery, and most patients can be managed conservatively.

In the present study, only one case of dislocation of the hip joint was detected in group C. This dislocation occurred one month after the initial surgery, during sports rehabilitation, and was treated with closed reduction under anaesthesia. Regardless of the analgesic protocol used by the anaesthesiologists, postoperative pain was well controlled in all patients, with a further reduction in the VAS score in patients who underwent the minimally invasive procedure. The anterior approach guaranteed a speedy functional recovery with reduced pain levels. Patients treated with this approach achieved full recovery approximately seven days earlier than patients treated with the posterolateral procedure, and about 15 days earlier than patients treated with the lateral approach. The posterolateral approach guaranteed a better quality of joint ROM, with an almost total recovery of the essential hip in patients with high functional demands. At two years from the initial surgery, the outcomes of all three groups appeared to be similar, although significant differences were observable during the first few months of follow-up.

Conclusions

In conclusion, given the recently acquired greater awareness of the advantages offered by the minimally invasive direct anterior approach used for hip arthroplasty, this thesis aimed to validate this surgical technique as a safe and efficient means to reduce morbidity and accelerate functional recovery. In fact, the anterior approach has produced good clinical outcomes in the short term (3-6 months postoperatively), especially in relation to a lower degree of blood loss, minimal pain and rapid recovery. This approach facilitates general patient recovery and the functional recovery of the hip treated, especially in the elderly who require a rapid functional recovery to enable a speedy return to a decent quality of life. The quality and quantity of the ROM of the hip joint is better in patients treated with the posterolateral approach. This enhances the function of the new artificial joint, and becomes an important feature for patients with high functional demands.

The posterolateral approach resulted more advantageous in terms of functional recovery and tropism at the 12-month follow-up point.

Given the previous notions, the lateral approach does not produce a good initial outcome: the recovery is delayed when compared with the other approaches, and pain persists for a few months. Although these features resulted statistically significant in the early months of the study, the WOMAC and HHS evaluations showed that two years after the initial surgery, the procedures overlap in terms of results and overall condition of the patient.

The choice of surgical approach should therefore be made by taking into account the requirements of the patient, in particular in terms of pain elimination and/or total functional recovery of the joint.

To reach an ideal decision for the individual patient, the following guidelines should be followed:

1. The anterior approach should be used in patients with blood disorders, as well as obese patients, or elderly patients who require a fast recovery.
2. The lateral approach should be used when a fast recovery is required, together with low risk of sciatic nerve injury and joint dislocation. The results of this approach are similar to those of the other two methods at two years after the initial surgery.
3. The posterolateral approach provides excellent joint recovery standards, with the end result being very close to the anatomy of a normal hip joint. This allows the new artificial joint to function in a similar manner to a normal joint. This approach is suitable for active young patients who wish to be able to resume their habitual activities, above all sports.

References

1. McAuley JP, Szuszczewicz ES, Young A, Engh CA Sr. Total hip arthroplasty in patients 50 years and younger. Clin Orthop Relat Res 2004; 418:119–125.
2. Szendrõi M, Sztrinkai G, Vass R, Kiss J. The impact of minimally invasive total hip arthroplasty on the standard procedure. Int Orthop 2006; 30:167–171.
3. Petty W: Total Joint Replacement-§VI, Lower Extremity Replacement: The Hip. Philadelphia, Pa, WB Saunders, 1991, pp 189-465.
4. McKee GK, Watson-Farrar J: Replacement of arthritic hips by the McKee- Farrar prosthesis. J Bone Joint Surg [Br] 1966; 48:245-259.
5. Chamley J: Total hip replacement. JAMA 1974; 230:1025-1028.
6. Charnley J: Low Friction Arthroplasty of the Hip: Theory and Practice. Berlin, Germany, Springer-Verlag, 1979, pp 332-345.
7. Spotorno L. An emerging gold standard for uncemented hip replacement? The CLS system: a 16-year review. Int Orthop 2000;24(Suppl):S16.
8. Robinson RP, Lovell TP, Green TM. Hip arthroplasty using the cementless CLS stem. A 2-4 years experience. J Arthroplasty 1994;9:177–92.
9. Dorr LD. Single-incision minimally invasive total hip arthroplasy. J Bone Joint Surg (Am) 2003;85-A:2236.
10. Speranza A, Iorio R, Ferretti M, D'Arrigo C, Ferretti A. A lateral minimal-incision technicque.
11. Wolson ST, Mow CS, Syquia JF, Lannin JV, Schurman DJ. Comparison of primary total hip replacements performed with a standard incision or a mini-incision. J Bone Joint Surg (Am) 2004;86-A:1353-8.
12. Jolles BM, Bogoch ER. Posterior versus lateral surgical approach for total hip arthroplasty in adults with osteoarthritis. Cochrane Database Syst Rev. 2004;1:CD003828.

13. Barber TC, Roger DJ, Goodman SB, Schurman DJ. Early outcome of total hip arthroplasty using the direct lateral vs the posterior surgical approach. Orthopedics. 1996;19:873–875.
14. Berry DJ, von Knoch M, Schleck CD, Harmsen WS. Effect of femoral head diameter and operative approach on risk of dislocation after primary total hip arthroplasty. J Bone Joint Surg Am. 2005;87:2456–2463.
15. Kwon MS, Kuskowski M, Mulhall KJ, Macaulay W, Brown TE, Saleh KJ. Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res. 2006;447:34–38.
16. Malchau H, Herberts P, Eisler T, Garellick G, Soderman P. The Swedish Total Hip Replacement Register. J Bone Joint Surg Am.2002;84(suppl 2):2–20.
17. Wenz JF, Gurkan I, Jibodh SR. Mini-incision total hip arthroplasty: A comparative assessment of peri-operative outcomes. Orthopedics. 2002;25(10):1031-43.
18. DiGioia AM 3rd, Plakseychuk AY, Levison TJ, et al. Miniincision technique for total hip arthroplasty with navigation. J Arthroplasty. 2003;18(2):123-8.
19. Sculco TP, Jordan LC. The mini-incision approach to total hip arthroplasty. Instr Course Lect. 2004;53:141-7.
20. Howell JR, Masri BA, Duncan CP. Minimally invasive versus standard incision anterolateral hip replacement: A comparative study. Orthop Clin North Am. 2004;35(2):153-62.
21. Smith-Petersen, M. N. Approach to and exposure of the hip joint for mold arthroplasty. J. Bone Joint Surg. 31-A:40– 46, 1949.
22. Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg Br. 1982;64:17-9.
23. McFarland B, Osborne G. Approach to the hip. A suggested improvement on Kocher's method. J Bone Joint Surg Br 1954;36B(3):364-7.

24. Mulliken BD, Rorabeck CH, Bourne RB, et al. A modified direct lateral approach in total hip arthroplasty. J Arthroplasty. 1998;13(7):737-46.
25. Kellgren J, Lawrence J. Radiologic assessment of osteoarthritis. Ann Rheum Dis 1957;16 : 494-501
26. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969 Jun;51(4):737-55.
27. Bellamy N Buchanan WW et al. Validation study of WOMAC: A health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol. 1988; 15: 1833-1840.
28. Rosencher N, Kerkkamp HE, Macheras G, Munuera LM, Menichella G, Barton DM, et al. OSTHEO Investigation. Orthopedic Surgery Transfusion Hemoglobin European Overview (OSTHEO) study: blood management in elective knee and hip arthroplasty in Europe. Transfusion 2003;43:459-69.
29. Wright JM, Crockett HC, Delgado S, Lyman S, Madsen M, Sculco TP Mini-incision for total hip arthroplasty: a prospective, controlled investigation with 5-year follow-up evaluation. 2004;J Arthroplasty 19:538–545.
30. Flören M, Lester DK. Durability of implant fixation after less-invasive total hip arthroplasty. J Arthroplasty 2006;21:783– 790.
31. McCollum DE, Gray WJ. Dislocation after total hip arthroplasty: causes and prevention. Clin Orthop 1990;261:159–170.
32. Gore DR, Murray MP, Sepic SB, Gardner GM. Anterolateral compared to posterior approach in total hip arthroplasty: differences in component positioning, hip strength, and hip motion. Clin Orthop Relat Res. 1982;165:180–187.
33. Mallory TH, Lombardi AV Jr, Fada RA, Herrington SM, Eberle RW. Dislocation after total hip arthroplasty using the anterolateral abductor split approach. Clin Orthop Relat Res. 1999;358:166–172.

34. Vicar AJ, Coleman CR. A comaprison of the anterolateral, transtrochanteric, and posterior surgical approaches in primary total hip arthroplasty. Clin Orthop Relat Res 1984;188:152–159.
35. Pierson JL, Hannon TJ, Earles DR. A blood-conservation algorithm to reduce blood transfusion after total hip and knee arthroplasty. J Bone Joint Surg Am .2004;86:1512-8.
36. Rosencher N, Kerkkamp HEM, Macheras G, Munuera LM, Menichella G, Barton DM et al. Orthopedic Surgery Transfusion Hemoglobin European Overview (OSTHEO) study: blood management in elective knee and hip arthroplasty in Europe. Transfusion .2003;43:459-69.
37. Wenz JF, Gurkan I, Jibodh SR. Mini-incision total hip arthroplasty: a comparison assessment perioperative outcomes. Orthopaedics 2002;25:1031.
38. Goldstein WM, Branson JJ, Berland KA, Gordon AC. *Minimal-incision total hip arthroplasty*. J Bone Joint Surg Am 2003;85-A(Suppl 4):33-8.
39. Chimento G, Pavone V, Sharrock N, Khan B, Cahill J, Sculco T. *Minimallyinvasive total hip arthroplasty.* J Arthroplasty 2005;20:139-44.
40. Wenz JF, Gurkan I, Jibodh SR. Mini-incision total hip arthroplasty: a comparative assessment of perioperative outcomes. Orthopedics .2002;25:1031-43.
41. Wright JM, Crockett HC, Delgado S, Lyman S, Madsen M, Sculco TP. Mini-incision for total hip arthroplasty. A prospective, controlled investigation with 5-year follow-up evaluation. J Arthroplasty. 2004;19:538-45.
42. Rachbauer F., Krismer M. Minimalinvasive huftendoprothetik uber den anterioren zugang . oper Orthop Traumatol. 2008;20:239-251.
43. Ladermann A., Ceroni D., Magistris M., Hoffmeyer P. Lésions du nerf sciatique en chirurgie de la hanche. Revue de chirurgie Orthopédique et Traumatologique. 2005 ;91,7 :637-41.

44. Stone RG, Weeks LE, Hajdu M, Stinchfield FE. Evaluation of sciatic nerve compromise during total hip arthroplasty. Clin Orthop 1985;201:26 –31.
45. Schmalzried TP, Amstutz HC, Dorey FJ. Nerve palsy associated with total hip replacement: risk factors and prognosis. J Bone Joint Surg Am 1991;73:1074–80.
46. Simmons C Jr, Izant TH, Rothman RH, et al. Femoral neuropathy following total hip arthroplasty: anatomic study, case reports, and literature review. J Arthroplasty 1991;6(Suppl):57– 66.
47. Siliski JM, Scott RD. Obturator-nerve palsy resulting from intrapelvic extrusion of cement during total hip replacement: report of four cases. J Bone Joint Surg Am 1985;67:1225– 8.
48. Donofrio PD, Bird SJ, Assimos DG, Mathes DD. Iatrogenic superior gluteal mononeuropathy. Muscle Nerve 1998;21:1794–6.
49. Edwards BN, Tullos HS, Noble PC. Contributory factors and etiology of sciatic nerve palsy in total hip arthroplasty. Clin Orthop 1987;218:136–41.
50. Rothman RH: Complications, chap 9, In Booth RE, Balderston RA, Rothman RH (Eds): Total Hip Arthroplasty. Philadelphia, Pa, WB Saunders, 1988, pp 174-218