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Total Hip Arthroplasty via Direct Anterior Approach: Clinical Considerations and Physiotherapy Management

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Abstract

Total hip arthroplasty (THA) is acknowledged to be one of the most successful procedures in the field of orthopaedic surgery. Over the last 15 years, the direct anterior approach (DAA) has generated scientific interest because of its soft-tissue preserving nature. DAA is a minimally invasive surgical technique and the patient is usually discharged from hospital 3 to 4 days after the operation. During the early postoperative period, appropriate physiotherapy aims to restore the mobility of the operated hip. The in-hospital physiotherapy should be continued at home, with certain precautions taken to safeguard soft-tissue repair healing and avoid hip dislocation. Additionally, the bone ingrowth in THA-surfaces (osseointegration) must be taken into account when evaluating the degree of postoperative weight-bearing during gait, as well as the hip-joint loading during postoperative physiotherapeutic exercises. Physiotherapy is also essential for restoring any preoperative deficit in the operated limb's abductor muscles during the patient's gradual return to everyday activities. The purpose of this article is to discuss well-documented postoperative considerations that could be useful for DAA-surgeons and physiotherapists to minimise the risk of postoperative complications and to achieve the best possible functional health outcome for their patients.

Keywords: Osteoarthritis; Hip prosthesis implantation; Osseointegration; Weight-bearing; Exercise performance

Abbreviations: BW: Body Weight; DAA: Direct Anterior Approach; MIS: Minimally Invasive Surgical Technique; SLR: Straight Leg Raise; THA: Total Hip Arthroplasty

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Introduction

Total hip arthroplasty (THA) is recognised worldwide as one of the most successful procedures in the field of orthopaedic surgery. Some have even gone so far as to call it the "surgery of the century" [1]. To patients with end-stage osteoarthritis of the hip, THA offers significant pain relief, increased functional ability, and improved quality of life [2]. In recent years, there has been growing interest in the minimally invasive surgical (MIS) techniques that are used for the performance of primary cementless THA. The advantages of these techniques include less soft tissue trauma, a smaller amount of blood loss*, less postoperative pain, a shorter hospital stay*, better aesthetic appearance of the incision, and a faster recovery time [3,4].

Over the last 15 years, the direct anterior approach (DAA) to THA has generated scientific interest, because of its soft-tissue preserving nature (intramuscular and internerve technique), combined with the relatively low risk of dislocation in comparison to other MIS techniques [5]. DAA is an MIS technique where the patient is usually discharged from hospital 3 to 4 days after the operation [6]. However, some studies have reported equivalent dislocation [7,8], or five-year revision rates [9] for DAA compared to other surgical approaches. Despite those controversial findings, in some cases current rehabilitation practice seems to be guided more by personal and institutional factors (e.g. rehabilitation setting) rather than by scientific data [10-12]. It has been reported that some surgeons who perform THA via DAA recommend very few postoperative precautions [13], or suggest that physiotherapy is not necessary after discharge [14]. This indicates that the experience and preferences of surgeons and physiotherapists play a major role in postoperative management [15].

Nevertheless, physiotherapeutic rehabilitation after primary THA surgery is generally accepted as a standard and essential treatment [16] that aims to minimise complications such as hip dislocation, wound infection, deep vein thrombosis and pulmonary embolism, and to maximise the patient's functionality and independence [17,18]. Although physiotherapy can be adjusted to the patient's clinical characteristics, such as preoperative muscle strength and functionality, and factors related to the selected surgical approach and the type of implant prosthesis [18], it has been reported that less than 46% of THA patients received physiotherapy after discharge [10].

Literature Review

This article will review the well-documented postoperative considerations, regarding the performance of DAA technique as well as implant specifications and patients' clinical characteristics that should be taken into account in the physiotherapeutic management of patients who have undergone THA via DAA. *The aim is* to shed light on the justified role of these considerations, which could be useful for DAA-surgeons and physiotherapists to achieve the best possible postoperative recovery, to minimise the risk of short- and long-term complications, and to give their patients the best possible restoration of function.

Direct anterior approach

The anterior-based incision uses the interval to the hip joint through the tensor fasciae latae (TFL) and the sartorius muscles. Smith-Peterson published the first description of the classical anterior approach in 1917 [19]. The Judet brothers described the procedure with the use of a fracture table in 1950 [20]. In 2005, Matta et al. described the anterior minimally invasive technique [21]. Since then, the technique has further progressed with the use of modern arthroplasty implants, fluoroscopy, and even computer navigation [22].

There are two main variations of the DAA technique: one uses a traction-specialised orthopaedic table [14,22,23], the other a standard surgical table [24,25]. The surgical procedure is similar in both cases, starting with the patient placed in a supine position [26].

When surgeons use a traction-specialised orthopaedic table, a perineal post is necessary to stabilise the patient and act as a counterpoint for gentle traction of the operative limb. A well-padded perineal post can avoid concerns about pudendal nerve compression from traction in the supine position. Well-padded boots are placed on the patient's feet and are secured to the traction arms of the table. The operative limb is not draped free, but is attached to a mobile spar that can apply traction, rotation and angulation to the leg in all directions. The contralateral hip is placed in neutral rotation, extension and abduction-adduction to serve as a radiographic control for the operated side. The operative limb is set in slight internal rotation to enhance the landmark of the natural bulge of the tensor fascia latae (TFL) muscle [23].

When a standard surgical table is used, the patient is positioned with the hip located over the table break, which can be reflexed to allow hyperextension of the hip joint. The contralateral limb is typically draped into the field and a mayo stand placed alongside to allow for a "figure-four" adduction position during the femoral exposure [14,25].

In both forms of DAA, incisions vary by surgeon; however, most authors rely on the anterior superior iliac spine and greater trochanter as anatomic landmarks for reference [14,22-25]. Dissection is taken deep to expose the overlying fascia of the TFL, which is then incised along its fibres. Blunt dissection is performed under the medial fascia and the interval is developed between the sartorius and the TFL. The medial side of the muscle is retracted laterally, sparing the aponeurosis of the sartorius in order not to injure the femoral cutaneous nerve. The ascending branches of the lateral circumflex femoral artery and vein are identified over the intertrochanteric line and cauterised, and the anterior hip capsule is exposed. Specific DAA retractors are useful for exposure. A cobra type retractor is placed superior to the lateral capsule to retract the abductors and a second large Hohmann type retractor is placed inferior to the femoral neck. A curved third retractor may be useful proximally to elevate the iliopsoas and rectus femoris muscles from the anterior capsule. The anterior capsule is incised (T-shape, L-shape, horizontal H-shape) and tagged for retention and later repair [14,22-25].

On the traction-specialised orthopaedic table, after the capsulotomy, the femoral neck osteotomy is made with the head in situ, using an oscillating saw in order to prevent a femoral fracture that could occur during coxofemoral dislocation. Before the femoral neck cut, the traction is increased by about 1 cm. The femoral head corkscrew is used to remove the head, after which the traction is released. The lower limb has already been externally rotated 45° to extract the femoral head. This position relaxes the iliopsoas and allows adequate placement of the retractors. External rotation of the femur by about 45° facilitates acetabular exposure [23].

On the standard surgical table, the femoral neck osteotomy can then be performed either with a single cut or, as some prefer, a "napkin-ring" type parallel two-cut technique to facilitate removal of the femoral head. An osteotome can be used to complete the cuts. Insertion of the corkscrew through the cortical side of the femoral head, or through the femoral neck cut, will help spin the head and rupture the ligamentum flavum, facilitating the head removal [14,26].

Whichever type of table is used for the DAA, visualisation of the acetabulum can be achieved with the use of three retractors (inferior–anterior–posterior). A spiked Hohmann retractor is placed on the anterior–inferior acetabular wall, under the acetabular transverse ligament. A similar Hohmann retractor is placed on the anterior acetabulum, with the spike of the retractor resting directly on the bone to avoid any possibility of femoral nerve injury. It should not be pulled too hard so as not to weaken

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the anterior wall. Finally, the third retractor is placed behind the posterior wall and pushes the femur away from the surgeon's area of focus, while protecting the tensor muscle [14,22-26]. An inferior capsular release may be useful for exposure. Reaming proceeds as in other approaches, medially at first to reach the true floor, then to the anatomic position. The acetabular component is inserted under fluoroscopic guidance in all patients, and the lower limb lengths are compared intraoperatively using imaging after hip reduction with the trial components. The acetabular prosthesis is inserted with a curved handle inserter that reduces pressure on the distal wound. Once the prosthesis has been inserted, the liner is introduced and any acetabular osteophytes are removed. Screw fixation of the acetabular component may be added at the surgeon's discretion, followed by liner impaction [14,22-26].

The femoral preparation is the most demanding part of this technique. On the traction-specialised orthopaedic table, femoral exposure is initiated by external rotation of the femur up to 90°. A proximal femoral hook is placed for elevating the proximal femur to facilitate exposure. The limb is extended by lowering the leg to the floor followed by adduction of the extremity [22,23].

On the standard surgical table, femoral exposure is accomplished by placing the operative limb in the "figure-four" adduction position, under the contralateral limb (**Figure 1a**), thus applying 20-30° of adduction and external rotation to the femur [25].

In both DAA formats, a double-pronged retractor is placed posteriorly to the greater trochanter and a cobra type retractor is placed medially to the neck cut. Release of the posterior joint capsule is performed by a vertical episiotomy-type incision in line with and down to the greater trochanter, extending superior to its apex. Limiting the releases done posteriorly is thought to impart improved stability by maintaining posterior structural integrity. The release is extended to the piriformis fossa, followed by the piriformis, the gemelli and the obturator internus until sufficient exposure is achieved. Preserving the obturator externus is important for maintaining hip stability and it should not be released unless necessary, as this effects the most direct medial pull of the femur on the pelvis, and the femur can be lifted up with the Hohmann retractor, which is behind the greater trochanter [24,25]. The extent of soft tissue release varies among different patients, but by proceeding step by step satisfactory proximal femoral exposure can be gained in every patient. Fluoroscopy can be used to evaluate the canal fit of the femoral prosthesis and the overall position. Trial reduction is performed with an appropriate test head, stability is assessed over extreme ranges of movement and the limb length is checked. Stability of the hip is confirmed and final fluoroscopic imaging is used to ensure accurate positioning [14,23].

Closure of the wound is initiated, with repair of the capsule followed by closure of the TFL fascia with either running or interrupted sutures. The use of a drain is optional. The subcutaneous tissue is closed with a resorbable suture and the skin is closed using the technique of choice [14,22,23,25,26].

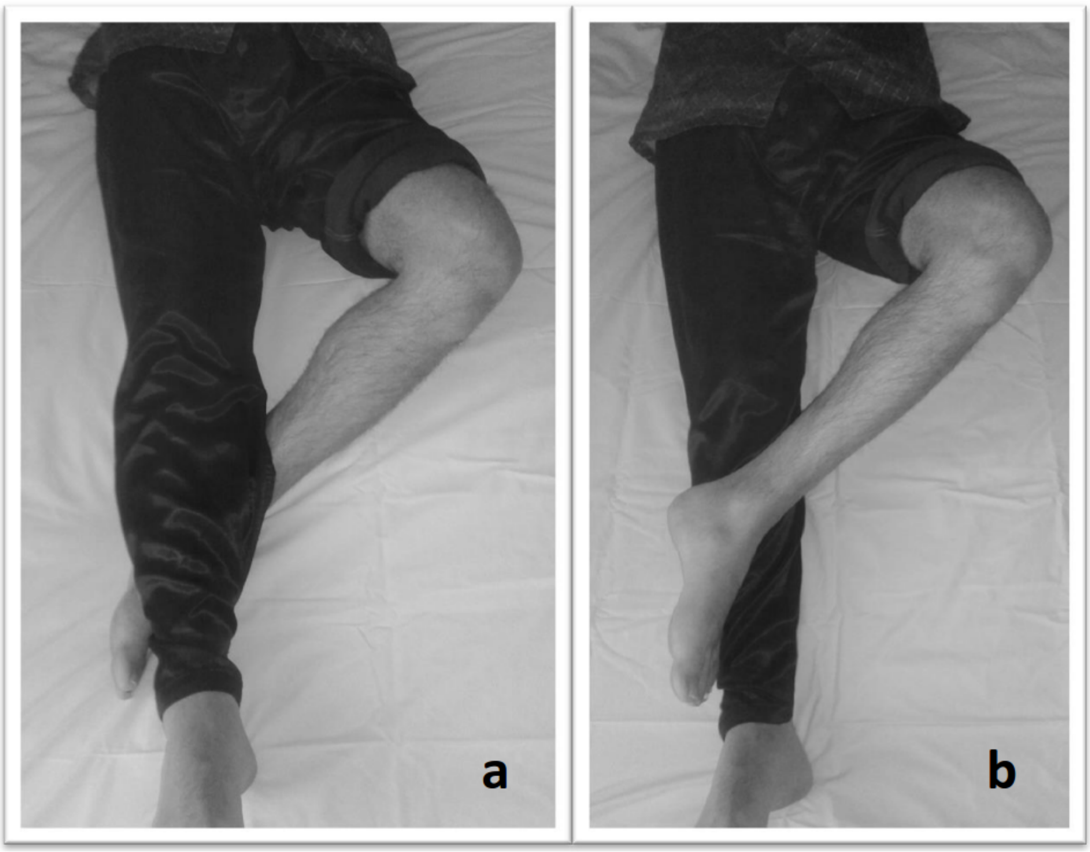

Figure 1 The "figure-four" position: a. the operated limb under the contralateral limb, b. the operated limb over the contralateral limb.

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Considerations regarding DAA technique

As a THA surgical technique, DAA does not result in direct or excessive muscular damage [5,27]. However, during surgical procedures, the adjacent soft tissues are significantly strained. It has been reported that the degree of TFL traction during surgery varies depending on the surgeon's experience or skill and that DAA-induced TFL injury results in a decrease in hip abduction moment, even one year after the surgery [28,29]. Additionally, excessive tension on the posterior femoral neck by the Hohmann retractor for achieving sufficient exposure of the femoral shaft may result in damage to the fibres of the gluteus medius around the insertion of the greater trochanter [30,31]. In a cadaveric study, it was found that 31.3% of the muscular area of the TFL, 8.5% of the muscular area of the gluteus minimus, and 2.6% of the muscular area of the gluteus medius were damaged during DAA [32].

On the other hand, the incised articular anterior and inferior capsule is repaired, but repair of the posterior capsule and subperiosteal release of the short external rotators cannot always be achieved [33].

Considerations regarding the implants

DAA is usually used for primary THA and in the majority of cases a cementless prosthesis is implanted. Cementless implants are inserted in the femur bone canal using the "press-fit" technique, thus leading to primary stability of the implant through the pre-stressed state of bone tissue [34-36]. Primary stability is defined as the stability of the implant just after the surgical insertion. Although the implant's insertion may damage bone tissue, it also triggers a cascade of wound healing events that stimulates osseointegration (bone ingrowth in THA surfaces) [37]. The process of osseointegration reflects an anchorage mechanism that allows non-vital components to be reliably incorporated into living bone and persists under all normal conditions of loading [38,39]. The main steps of bone regeneration are: (a) the deposition of an extracellular matrix or osteoid tissue, an unmineralised collagen-rich tissue; (b) mineralisation of the osteoid by hormonal stimulation of local concentrations of calcium and phosphate ions to form woven bone; and (c) remodelling of woven bone to mature bone. Therefore, the impact of osseointegration phenomena is to strengthen the implant's secondary stability, which is a function of healing time [37].

The early peri-implant trabecular bone formation ensures tissue anchorage that corresponds to biological fixation of the implant. Biological fixation differs from the primary (mechanical) stability that is easily obtained during the implant insertion. Primary stability depends on the surgical technique, implant design and implantation site; it limits micro-motion of the implant in the early phases of tissue healing and favours successful osseointegration [40]. Different materials (titanium, tantalum, aluminium, niobium, nickel, zirconium, and hafnium), shape, length, diameter, implant surfaces (sand-blasted, acid etched or anodically roughened) and coatings (titanium plasma-sprayed or hydroxyapatite-coated) have been proposed to ensure primary stability and enhance osseointegration [41-43]. During bone healing, micro-motion smaller than 40-70 μm allows bone tissue ingrowth; however, an excessive level (typically greater than 150 μm) results in the formation of peri-prosthetic fibrous tissue instead of an osseointegrated interface [37]. The presence of fibrous tissue affects the load-bearing capacity of the implant and, since micro-motions are enhanced, leads to a vicious circle that may be responsible for implant failures [44,45].

Considerations regarding the patient's clinical characteristics

Specific factors (clinical characteristics or habits) that inhibit osseointegration include osteoporosis, advanced age, nutritional deficiency, smoking and renal insufficiency [43]. Above all, osteoporosis is the most aggravating factor. In vitro and animal research has shown slower biomaterial osseointegration and a higher rate of prosthetic device failures in the presence of osteoporosis [46,47].

Osteoporosis seems to compromise the biological and mechanical fixation of implants used for joint arthroplasty. The increased risk of implant failure in osteoporotic bone is secondary to various factors that alter its structural, biological and mechanical properties. Osteoporosis seems to affect cell proliferation, protein synthesis and cell reactivity to local factors [48]; while the number and activity of cells of the osteogenic lineage (mesenchymal cells and osteoblasts) is decreased, the number and activity of osteoclasts is increased, and vascularisation is impaired [49].

THA is a hip joint reconstruction method, but it does not correct the patients' preoperative muscle-related disabilities. Another factor is the orthopaedic disease that leads the patient to undergo THA-DAA. The vast majority of patients who undergo THA suffer from end-stage primary or secondary hip osteoarthritis [50]. The preoperative disability seen in patients with hip osteoarthritis is directly linked to the loss of muscle strength and range of joint motion [51]. In one study that evaluated the gluteus maximus, medius, and minimus muscles using MRI, studying the muscles' volume asymmetry and fatty infiltration (graded with the Goutallier classification system) [52,53]. In another study, gluteal muscles were found to atrophy on the affected side in the osteoarthritis group, compared to both the contralateral side and the control group, while increased gluteal fatty infiltration and hip strength deficits were evident in the affected hips of osteoarthritis patients and the severity of the osteoarthritis was related to the extent of atrophy and fatty deposits [53]. The patients with grade 3 hip osteoarthritis according to the Kellgren–Lawrence classification system [54] had Goutallier grade 2 or 3 fatty infiltration [53]. Abductor muscle dysfunction could therefore lead to a lack of pelvic stability and antalgic gait, since the gluteus medius is responsible for stabilisation of the hip and pelvic rotation during gait [55] and the gluteus minimus stabilises the head of the femur within the acetabulum during the gait cycle [56]. It was also reported that the decreased strength of hip abduction and internal rotation found in osteoarthritis patents is consistent with the decreased volumes of these muscles [53]. In addition, significant atrophy in the gluteus maximus muscle was observed in the hip osteoarthritis limb [53]. The gluteus maximus plays an essential role in bipedal locomotion and any deficit in its functioning can compromise many aspects of the gait cycle [57], and other everyday activities, such as sit-to-stand [58]. The upper fibres of the gluteus maximus act along with the hip abductors during loading and single limb stance, while its lower fibres are considered as a major hip extensor and external rotator and are also active at heel strike during gait, helping to absorb ground reaction forces [53]. Atrophy of the gluteus maximus may be a response to the reduced stimulus as a result of the declining hip extension movement. It is likely that such atrophy occurs predominantly or initially in the lower gluteus maximus, given its role as a hip extensor. A decrease in hip extension during the late stance phase of gait has been identified as a key feature in a population with hip osteoarthritis [59] and can be an important determinant of the progression of the disease [60]. The disuse of gluteal muscles can lead to increased levels of disability and reduced mobility, both of which are commonly seen in populations with hip osteoarthritis [53].

Physiotherapy management

Early postoperative rehabilitation after a THA focuses on reducing pain, preventing complications such as subluxation and thromboembolic disease, regaining mobility, strength and flexibility, and training patients to safely perform everyday life activities, enabling them to live as independently as possible [61,62].

During the DAA technique, the TFL, the gluteus minimus, the gluteus medius and the short external rotators are injured or strained, while the articular anterior capsule is incised and repaired, but it is not always possible to repair the posterior capsule [30-33]. Patients should be educated as to what range of motion is to be expected after the implantation and what movements and actions are to be avoided to prevent dislocation, especially in the early postoperative phase. DAA surgeons often apply limits only to extension and external rotation [13], or specify no hip precautions [22]. However after any DAA procedure, in order to protect the healing of the muscles and anterior capsule, adduction past neutral position, external rotation past 45° and hyperextension should be avoided for at least 6 weeks [33]. In the supine position the abduction pillow is not necessary, but when the patient is lying in a lateral position a pillow between the legs will prevented hip adduction. In addition, if the short external rotators and posterior capsule are incised, during the same period (6 weeks) the patient should refrain from deep sitting or deep trunk bending with the hips flexed above 90°, because this can cause a positional dorsal dislocation [33,63]. Anterior dislocation may occur as a result of external rotation and adduction of the extended operated hip joint [63], or if the patient adopts the “figure-four” adduction position that is used for the femoral exposure when a standard surgical table is used [25] (**Figure 1a, 1b**).

Another important issue is the preservation of the osseointegration process. After the implantation, the early peri-implant trabecular bone formation begins at 10 to 14 days after surgery [43]; the osseointegration process will take approximately four to 12 weeks [64]. At 12 weeks a mixed bone texture of woven and lamellar matrix can be found around the implants [43], and the bone regeneration and remodelling will continue for up to three years [64]. However, avoiding high loads at the bone-stem-interface throughout the first postoperative weeks appears to be beneficial for optimal bone healing. A valid classification for “high” or “low” load levels depends on the type of the implant, the osteoarthritis, the patient’s age and the possible presence of osteoporosis; therefore, it cannot be generalised [65]. These facts should be taking into account in the surgeon’s decision about the postoperative amount of weight-bearing during gait and the use of the proper assistive device, as well as the hip joint loading during postoperative physiotherapeutic exercises [65]. It remains unclear whether the term “full weight-bearing” refers to 100% of the body weight (BW). When a person is walking or ascending/ descending stairs, the hip-joint contact forces are greater. In any case, it has been reported that, without an assistive device, the magnitude of the joint-contact force during double-limb stance was 100% BW. During ipsilateral single-limb stance the joint-contact force is 210% BW, and during the stance phase of gait the peak force typically is 260% to 280% BW, with the resultant force located on the anterosuperior portion of the acetabulum component [66]. When a walker is used during gait, the joint-contact force is 100% BW, reaching 120% BW at ipsilateral single-limb stance. In ambulation using two crutches, the joint-contact force is 150% BW, while when contralateral hand assistance is used it is 210% BW [66]. Considered these findings, for 4 to 6 weeks the prosthesis-bone interface must be protected in order to allow osseointegration, using a walker or, in the case of young patients with good balance ability and bone quality, two crutches during gait. In the presence of osteoporosis, the surgeon may decide to increase the number of weeks for which the patient should use a walker during gait in order to protect the osseointegration. Beyond this time interval, walking with a crutch may be permitted for as long as the surgeon judges suitable, but for no longer than 12 weeks, by which time the critical phase of osteogenesis has been completed [43].

During ascending/descending stairs, the force is 260% BW [66]. In order to prevent joint overloading, the patient must be educated to perform this activity correctly. The proper way is one step at a time, using the handrail and raising the contralateral limb first, then the assistive device and the operated limb together; while descending, the assistive device and the operated limb are moved first, then the contralateral limb. After the 12-week period, if patients have acquired sufficient muscular strength and are free of pain, they may ascend and descend stairs normally [67].

Schwachmeyer et al studied the hip joint contact forces and moments that act during the physiotherapeutic exercises that are most commonly applied in the early postoperative period and compared their loads to those seen during full weight-bearing gait (set to 100%). They found that the resultant force peaks of isometric exercises that are often used during the first postoperative days—isometric contraction of gluteus maximus with knee flexed, isometric contraction of quadriceps and isometric hip abduction—were lower than the 100% of gait. During the active exercises in supine position—hip abduction with straight knee and with dorsiflexion, hip and knee flexion/ extension with the heel slide on surface (heel slides), pelvis tilt (anteriorly and posteriorly), hip flexion with straight knee [**straight leg raise** (SLR)] —the forces applied also remained below 100% of gait. However the torsional moment of SLR was 7 times higher

[65]. Previous studies reported that SLR applies a force of 150% to 180% of BW [66,68]. SLR is an exercise that is avoided during the early postoperative period, because of the high anteroposterior contact force that is applied to the reconstructed hip joint. When the hip is flexed from a supine position the exercise is performed against gravity and the loads act with a long lever arm. Initially, when the patient is free of pain and has good balance ability, the SLR exercise (hip flexion with straight knee) can be performed from the upright position up to 30 or 40 degrees as individually tolerated [67]. From a supine position it can be performed when the surgeon allows gait using one crutch [67].

Finally, special attention should be paid to the physiotherapeutic management of abductor muscles. Apart from the perioperative strain, the preoperative abductor muscle dysfunction seen in hip osteoarthritis patients could lead postoperatively to pelvic instability and an abnormal gait pattern (**Trendelenburg gait)**. Since the severity of osteoarthritis is related to the extent of atrophy and fatty deposits, rehabilitation programmes targeting these muscles could reverse or halt the progression of these structural and functional deficits [53].

Careful selection of the strengthening exercises is required in order to prevent excessive loading of the hip joint during their performance. Range of motion and abductor active exercises should be performed with gradual encumbrance in different body positions. Daniel et al estimated acetabular loading in upright and supine positions, and in side-lying lower limb abduction [69]. Abductor active exercises should be performed from positions of increasing difficulty that load the hip joint progressively, starting with a set of 8-10 repetitions as individually tolerated. The first position is supine on the bed for the first 2-3 postoperative weeks. The hip abduction active exercises are performed progressively: a. the midrange of motion, b. the midrange and end-range of motion (not past the neutral position) [70]. During the first 4-5 postoperative days, if the patient feels pain due to the surgical procedure, the exercise should be performed with the assistance of the physiotherapist, but not passively [67]. The next position is upright (4^{th} and 5^{th} week), where the hip abduction is performed in a. the inner range of motion and b. the inner and the mid-range of motion. Third, at the 6^{th} week, is the side-lying position, where hip abduction is performed a. in the end-range, b. in the end- and midrange (using a pillow between thighs), and finally c. in the full range of motion. The criterion for advancing the position and the range of motion with which the abductor exercise is performed is that the patient must complete a set of 15 repetitions without feeling any pain or fatigue [70]. With this progressive rehabilitation programme the gluteus maximus is also exercised as a secondary abductor muscle [67]. The strengthening isotonic exercises of the gluteal maximus as extensor require hip hypertension, a movement that must be avoided for at least 6 weeks after DAA [33].

Conclusion

As a THA surgical technique, DAA does not result in direct muscular damage and thus facilitates rapid recovery and early ambulation. DAA is a MIS technique, where the patient is usually discharged from hospital 3 to 4 days after the operation; therefore, postoperative physiotherapy is more essential. The postoperative physiotherapy after discharge should be continued for at least the first 4-6 postoperative weeks. In order to protect the healing of muscles and the anterior capsule, adduction past neutral position, external rotation past 45° and hyperextension should be avoided for at least 6 weeks. In addition, during the same period, patients should refrain from deep sitting or deep trunk bending with the hips flexed above 90°, and should avoid external rotation and adduction of the extended operated hip joint or the "figure-four" position.

Proper osseointegration must be preserved while the progressive physiotherapy programme is developing, taking into account the patient's clinical characteristics and needs. For 4 to 6 weeks the prosthesis-bone interface must be protected using a walker or, in the case of young patients with good balance ability and bone quality, two crutches during gait. In the presence of osteoporosis, the surgeon may decide to increase the number of weeks for which the patient must use a walker during gait in order to protect the osseointegration. Beyond this time interval, walking with a crutch may be permitted for as long as the surgeon judges suitable, but for no longer than 12 weeks, by which time the critical phase of osteogenesis has been completed. The resultant force peaks of isometric and active exercises that are often used during the first postoperative weeks are limited to below 100% BW, apart from SLR, which applies a force of 150% to 180% BW and very high torsional moment. Finally, special attention should be paid to the physiotherapeutic management of abductor muscles, since strength deficits will be evident in the osteoarthritis-affected hip. Range of motion and abductor active exercises should be performed with gradual encumbrance in different body positions, in order to prevent excessive loading of the hip joint during their performance. The strengthening isotonic exercises of the gluteus maximus require hip hypertension, a movement that must be avoided for at least 6 weeks after DAA.

After THA, physiotherapy is important to mobilise the patient and restore hip function. The physiotherapist's aim is therefore to increase muscle strength, improve joint mobility and train the patient to safely perform everyday life activities, preventing complications such as subluxation, enabling the patient to live as independently as possible. The aforementioned considerations—even when the soft-tissue preserving DAA technique has been used—are important to maximise the patient's strength and functionality so as to achieve an excellent recovery after THA.

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References

1 Learmonth ID, Young C, Rorabeck C (2007) The operation of the century: total hip replacement. Lancet 370: 1508-1519.

2 Ethgen O, Bruyère O, Richy F, Dardennes C, Reginster JY (2004) Health-related quality of life in total hip and total knee arthroplasty. A qualitative and systematic review of the literature. J Bone Joint Surg Am 86: 963-974.

3 Siddiqui NA, Mohandas P, Muirhead-Allwood S, Nuthall T (2005) A review of minimally invasive hip replacement surgery – current practice and the way forward. Curr Orthop 19: 247-254.

4 Bergin PF, Doppelt JD, Kephart CJ, Benke, MT, Graeter, JH, et al. (2011) Comparison of minimally invasive direct anterior versus posterior total hip arthroplasty based on inflammation and muscle damage markers. J Bone Joint Surg Am 93: 1392-1398.

5 Connolly KP, Kamath AF (2016) Direct anterior total hip arthroplasty: Comparative outcomes and contemporary results. World J Orthop 7: 94-101.

6 Ogonda L, Wilson R, Archbold P, Lawlor M, Humphreys P, et al. (2005) A minimal-incision technique in total hip arthroplasty does not improve early postoperative outcomes. A prospective, randomized, controlled trial. J Bone Joint Surg Am 87: 701–710.

7 Kwon MS, Kuskowski M, Mulhall KJ, Macaulay W, Brown TE, et al. (2006) Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res 447: 34-38.

8 Miller LE, Gondusky JS, Bhattacharyya S, Kamath AF, Boettner F, et al. (2018) Does surgical approach affect outcomes in total hip arthroplasty through 90 days of follow-up? A systematic review with meta-analysis. J Arthroplasty 33: 1296-1302.

9 Meneghini RM, Elston AS, Chen AF, Kheir MM, Fehring TK, et al. (2017) Direct Anterior Approach: risk factor for early femoral failure of cementless total hip arthroplasty: A multicenter study. J Bone Joint Surg Am 99: 99-105.

10 Okoro T, Ramavath A, Howarth J, Jenkinson J, Maddison P, et al. (2013) What does standard rehabilitation practice after total hip replacement in the UK entail? Results of a mixed methods study. BMC Musculoskelet Disord 14: 91.

11 Bandholm T, Kehlet H (2012) Physiotherapy exercise after fast-track total hip and knee arthroplasty: time for reconsideration? Arch Phys Med Rehabil 93: 1292–1294.

12 Westby MD, Brittain A, Backman CL (2014) Expert consensus on best practices for post-acute rehabilitation after total hip and knee arthroplasty: a Canada and United States Delphi study. Arthritis Care Res (Hoboken) 66: 411–423.

13 Carli AV, Poitras S, Clohisy JC, Beaule PE (2018) Variation in use of postoperative precautions and equipment following total hip arthroplasty: a survey of the AAHKS and CAS membership. J Arthroplasty 33: 3201–3205.

14 Gregor K, Krištof MP, Jure T, Klemen B (2019) The Direct Anterior Approach for Total Hip Arthroplasty without specific table: surgical approach and our seven years of experience. Res Arthritis Bone Study 1: RABS.000520.2019.

15 Eulenburg C, Rahlf AL, Kutasow A, Zech A (2015) Agreements and disagreements in exercise therapy prescriptions after hip replacement among rehabilitation professionals: a multicenter survey. BMC Musculoskelet Disord 16: 185.

16 Foran JRH, Fischer SJ (2017) Total Hip Replacement Exercise Guide American Academy of Orthopaedic Surgeons (AAOS).

17 Medical Advisory Secretariat (2005) Physiotherapy rehabilitation after total knee or hip replacement: an evidence-based analysis. Ont Health Technol Assess Ser 5: 1–91.

18 Păunescu F, Didilescu A, Antonescu DM (2013) Factors that may influence the functional outcome after primary total hip arthroplasty. Clujul Med 86: 121–127.

19 Post Z, Orozco F, Diaz-Ledezma C, Hozack W, Ong A (2014) Direct Anterior Approach for Total Hip Arthroplasty: indications, technique, and results. J Am Acad Orthop Surg 22: 595–603.

20 Judet J, Judet R (1950) The use of an artificial femoral head for arthroplasty of the hip joint. J Bone Joint Surg Br 32-B: 166-173.

21 Matta JM, Shahrdar C, Ferguson T (2005) Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res 441: 115-124.

22 Tatka J, Fagotti L, Matta J (2018) Anterior approach total hip replacement (THA) with a specialized orthopedic table. Ann Joint 3: 42.

23 Macheras GA, Galanakos SP, Koutsostathis S, Lepetsos P, Papadakis S, et al. (2015) Preliminary Results Using Anterior Minimally Invasive Surgery for Total Hip Arthroplasty. *Proceedings of the 71ᵒ Conference of Hellenic Association of Orthopaedic Surgery and Traumatology – EEXOT* 67: 91-97.

24 Moskal JT, Capps SG, Scanelli JA (2013) Anterior muscle sparing approach for total hip arthroplasty. World J Orthop 4: 12-18.

25 Holst DC, Angerame MR, Yang CC (2018) Surgical technique of direct anterior approach for total hip arthroplasty on a standard operating room table. Ann Joint 3: 34.

26 Galakatos GR (2018) Direct anterior total hip arthroplasty. Mo Med 115: 537-541.

27 Meneghini RM, Smits SA, Swinford RR, Bahamonde RE (2008) A randomized, prospective study of 3 minimally invasive surgical approaches in total hip arthroplasty: comprehensive gait analysis. J Arthroplast 23: 68–73.

28 Wesseling M, Meyer C, Corten K, Simon JP, Desloovere K, et al. (2016) Does surgical approach or prosthesis type affect hip joint loading one year after surgery? Gait Posture 44: 74–82.

29 Pospischill M, Kranzl A, Attwenger B, Knahr K (2010) Minimally invasive compared with traditional transgluteal approach for total hip arthroplasty: a comparative gait analysis. J Bone Joint Surg Am 92: 328–337.

30 Martin R, Clayson PE, Troussel S, Fraser BP, Docquier P-L (2011) Anterolateral minimally invasive total hip arthroplasty: a prospective randomized controlled study with a follow-up of 1 year. J Arthroplast 26: 1362–1372.

31 Yoo JI, Cha YH, Kim KJ, Kim HY, Choy WS, et al. (2019) Gait analysis after total hip arthroplasty using direct anterior approach versus anterolateral approach: a systematic review and meta-analysis. BMC Musculoskelet Disord 20: 63.

32 Meneghini RM, Pagnano MW, Trousdale RT, Hozack WJ (2006) Muscle damage during MIS total hip arthroplasty: Smith-Petersen versus posterior approach. Clin Orthop 453: 293–298.

33 Zahar A, Rastogi A, Kendoff D (2013) Dislocation after total hip arthroplasty. Curr Rev Musculoskelet Med 6: 350–356.

34 Berahmani, S, Janssen D, van Kessel S, Wolfson D, de Malefijt MW,

et al.(2015) An experimental study to investigate biomechanical aspects of the initial stability of press-fit implants. J Mech Behav Biomed Mater 42: 177-185.

35 Shirazi-Adl A, Forcione A (1992) Finite element stress analysis of a push-out test. Part II: Free interface with nonlinear friction properties. J Biomech Eng 114: 155-161.

36 Shultz TR, Blaha JD, Gruen TA, Norman TL (2006) Cortical bone viscoelasticity and fixation strength of press-fit femoral stems: finite element model. J Biomech Eng 128: 7-12.

37 Gao X, Fraulob M, Haïat G (2019) Biomechanical behaviour of the bone-implant interface: a review. J R Soc Interface 16: 20190259.

38 Brånemark PI (1983) Osseointegration and its experimental background. J Prosthet Dent 50: 399-410.

39 Rigo ECS, Boschi AO, Yoshimoto M, Allegrini SJr, Konig BJr, et al. (2004) Evaluation in vitro and in vivo of biomimetic hydroxyapatite coated on titanium dental implants. Mater Sci Eng C 24: 647-651.

40 Sennerby L, Thomsen P, Ericson LE (1992) A morphometric and biomechanic comparison of titanium implants inserted in rabbit cortical and cancellous bone. Int J Oral Maxillofac Implants 7: 62-71.

41 Kujala S, Ryhanen J, Danilov A, Tuukkanen J (2003) Effect of porosity on the osteointegration and bone ingrowth of a weight-bearing nickel-titanium bone graft substitute. Biomaterials 24: 4691-4697.

42 Mohammadi S, Esposito M, Cucu M, Ericson LE, Thomsen P (2001) Tissue response to hafnium. J Mater Sci Mater Med 12: 603-611.

43 Mavrogenis AF, Dimitriou R, Parvizi J, Babis GC (2009) Biology of implant osseointegration. J Musculoskelet Neuronal Interact 9: 61-71.

44 Giori NJ, Ryd L, Carter DR (1995) Mechanical influences on tissue differentiation at bone-cement interfaces. J Arthroplasty 10: 514-522.

45 Park JY, Davies JE (2000) Red blood cell and platelet interactions with titanium implant surfaces. Clin Oral Implants Res 11: 530-539.

46 Zhang H, Lewis CG, Aronow MS, Gronowicz GA (2004) The effects of patient age on human osteoblasts' response to Ti-6Al-4V implants in vitro. J Orthop Res 22: 30-38.

47 Fini M, Aldini NN, Gandolfi MG, Belmonte MM, Giavaresi G, et al. (1997) Biomaterials for orthopedic surgery in osteoporotic bone: a comparative study in osteopenic rats. Int J Artif Organs 20: 291-297.

48 Wong MM, Rao LG, Ly H, Hamilton L, Ish-Shalom S, et al. (1994) In vitro study of osteoblastic cells from patients with idiopathic osteoporosis and comparison with cells from non-osteoporotic controls. Osteoporos Int 4: 21-31.

49 Fini M, Giavaresi G, Torricelli P, Borsari V, Giardino R, et al. (2004) Osteoporosis and biomaterial osteointegration. Biomed Pharmacother 58: 487-493.

50 Murphy NJ, Eyles JP, Hunter DJ (2016) Hip Osteoarthritis: Etiopathogenesis and implications for management. Adv Ther 33: 1921–1946.

51 van Baar ME, Dekker J, Lemmens JA, Oostendorp RA, Bijlsma JW (1998) Pain and disability in patients with osteoarthritis of hip or knee: the relationship with articular, kinesiological and psychological characteristics. J Rheumatol 25: 125–133.

52 Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC (1994) Fatty muscle degeneration in cuff ruptures: Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res pp: 78-83.

53 Zacharias A, Pizzari T, English DJ, Kapakoulakis T, Green RA (2016) Hip abductor muscle volume in hip osteoarthritis and matched controls. Osteoarthritis Cartilage 24: 1727-1735.

54 Kellgren JH, Lawrence JS (1957) Radiological assessment of osteo-arthrosis. Ann Rheum Dis 16: 494-502.

55 Gottschalk F, Kourosh S, Leveau B (1989) The functional anatomy of tensor fasciae latae and gluteus medius and minimus. J Anat 166: 179–189.

56 Beck M, Sledge JB, Gautier E, Dora CF, Ganz R (2000) The anatomy and function of the gluteus minimus muscle. J Bone Joint Surg Br 82: 358–363.

57 Wilson J, Ferris E, Heckler A, Maitland L, Taylor C (2005) A structure review of the role of gluteus maximus in rehabilitation. N Z J Physiother 33: 95-100.

58 Yamada T, Demura SI (2009) Relationships between ground reaction force parameters during a sit-to-stand movement and physical activity and falling risk of the elderly and a comparison of the movement characteristics between the young and the elderly. Arch Gerontol Geriatr 48: 73-77.

59 Hurwitz DE, Hulet CH, Andriacchi TP, Rosenberg AG, Galante JO (1997) Gait compensations in patients with osteoarthritis of the hip and their relationship to pain and passive hip motion. J Orthop Res 15: 629-635.

60 Foucher KC, Schlink BR, Shakoor N, Wimmer MA (2012) Sagittal plane hip motion reversals during walking are associated with disease severity and poorer function in subjects with hip osteoarthritis. J Biomech 45: 1360-1365.

61 Stockton KA, Mengersen KA (2009) Effect of multiple physiotherapy sessions on functional outcomes in the initial postoperative period after primary total hip replacement: a randomized controlled trial. Arch Phys Med Rehabil 90: 1652-1657

62 Coulter CL, Scarvell JM, Neeman TM, Smith PN (2013) Physiotherapist-directed rehabilitation exercises in the outpatient or home setting improve strength, gait speed and cadence after elective total hip replacement: a systematic review. J Physiother 59: 219-226.

63 Dargel J, Oppermann J, Brüggemann G, Eysel P (2014) Dislocation Following Total Hip Replacement. Dtsch Arztebl Int 111: 884–890.

64 Zweymüller KA, Lintner FK, Semlitsch MF (1988) Biologic fixation of a press-fit titanium hip joint endoprosthesis. Clin Orthop Relat Res pp: 195–206.

65 Schwachmeyer V, Damm P, Bender A, Dymke J, Graichen F, et al. (2013) In vivo hip joint loading during post-operative physiotherapeutic exercises. PLoS ONE 8: e77807.

66 Davy DT, Kotzar GM, Brown RH, Heiple KG, Goldberg VM, et al. (1988) Telemetric force measurements across the hip after total arthroplasty. J Bone Joint Surg Am 70: 45-50.

67 Papathanasiou G, Stasi S (2019) Physical therapy rehabilitation after hip arthroplasty. Clinical Placement: Physiotherapy in Musculoskeletal Injuries and Disorders (04th edn), Chapter 3. Athens: University of West Attica, George Papathanasiou, Sophia Stasi.

68 Meftah M, Ranawat AS, Ranawat AS, Caughran AT (2018) Total hip replacement rehabilitation: progression and restrictions. In Giangarra CE, Manske RC, Brotzman SB (Eds). Clinical Orthopaedic Rehabilitation. A Team Approach (4th edn). PA Elsevier, Philadelphia.

69 Daniel M, Debevec H, Kristan A, Mavcic B, Cimerman M, et al. (2007) Acetabular forces and contact stresses in active abduction rehabilitation. In: Jarm T, Kramar P, Zupanic A (eds) 11th Mediterranean

Conference on Medical and Biomedical Engineering and Computing 2007. IFMBE Proceedings 16: 915-918.

70 Stasi S, Krasoulis K, Papathanasiou G (2011) Low-Energy Hip Fractures; Special Considerations Regarding Physical Therapy Intervention. Physiotherapy Issues 7: 83-94.