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ORIGINAL STUDY

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Total hip arthroplasty with a superior approach and in situ preparation of the femoral stem: technique and feasibility in a prospective series of 80 cases

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We report on the feasibility of a technique for total hip replacement with in situ preparation of the femoral stem through a superior approach and with the use of standard instruments.

From December 2017 to august 2018, 100 patients were recruited for total hip replacement. 80 patients underwent THA through a superior approach with femoral broaching before femoral neck cut. We evaluated feasibility, complications and early functional outcome.

There were no major complications. Postoperative leg length discrepancy was on average +0.6mm and offset -0.5mm. The mean acetabular cup inclination was 42.0° and the mean anteversion was 14.5°. The mean WOMAC score was 46 before, 76 at 1 month and 86 at 3 months after surgery. Functional scores (OARSI) were significantly improved at 3 months.

Superior in situ total hip replacement is a reliable and reproducible technique with an excellent clinical outcome. It is an iteration to the posterior approach, hence the learning curve is steep and if needed, conversion to a standard posterior approach is possible.

Keywords: hip; approach; superior; arthroplasty; replacement.

INTRODUCTION

The key factors for a successful outcome after total hip arthroplasty (THA) are an appropriate implant selection, a meticulous and minimal disruptive operative technique and an accurate reconstruction of the native hip anatomy. Recent progress in surgical technique is driven by the desire to minimalize tissue damage and improve early patient recovery. Several variations to the standard surgical approaches have been described that hold promise of minimal tissue disruption but in practice this advantage is only short-lived and is gone after days to weeks *(1, 2, 3)*. Clinical failure of a well-fixed implant is multifactorial, but often irreversible tissue damage and incorrect anatomical reconstruction play an important role in the unhappy hip arthroplasty patient and are the main drivers for short- and medium-term failure.

The aim of this study is to explore the feasibility of a superior approach to the hip, with in situ preparation of the femoral stem. The approach does

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

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not depend on a specific implant and is performed through a single incision. Musculotendinous damage is limited to the release of the internal obturator tendon. The preparation of the femoral stem is initiated before the femoral neck is cut. The approach is based on a technique first described by Murphy in 2004 *(4)*, and its subsequent variations as described by Chow in 2011 *(5)* and Roger in 2012 *(6)*. We report on the feasibility, outcome and complications of a consecutive series of 80 patients.

MATERIALS AND METHODS

The study was approved by the institutional review board, and a written consent was obtained before undergoing study-related analysis.

Clinical outcome

The data of a consecutive series of 80 patients (81 surgeries) eligible for hip replacement were collected in a prospective clinical database. Patient demographics such as age, weight, sex and BMI were recorded at the time of surgery. Hemoglobin (Hb) levels were recorded before and 1 day after the operation. The exclusion criteria included trauma, hip dysplasia requiring acetabular reconstruction, retained hardware and resurfacing procedures. Surgical time, length of stay and complication type, incidence and severity (ICD-10 code and Clavien-Dindo Grade) were recorded in the same clinical database.

Radiographic assessment (Fig. 1,2)

Preoperative templating was performed for all cases using the OrthoView templating software (OrthoView, Materialise, Belgium).

The center of rotation was measured on preoperative X-rays, the planned reconstruction and the postoperative radiographs. A line was drawn connecting the most distal point of the teardrops and height and offset of the center of rotation were calculated form this point as described by Takamatsu et al. *(7)*. The preoperative and postoperative femoral offset were calculated as the distance from the femoral axis to the center of rotation *(7)*. The total hip offset was calculated as the sum of femoral offset and acetabular offset.

The pre- and postoperative leg length discrepancy was calculated as the difference between the perpendicular length from a line passing through the most inferior part of both teardrops and the most prominent part of to the lesser trochanter *(8)*. The planned and actual insertion depth of the femoral stem was calculated as the distance from the

Figure 1. — Postoperative radiograph.

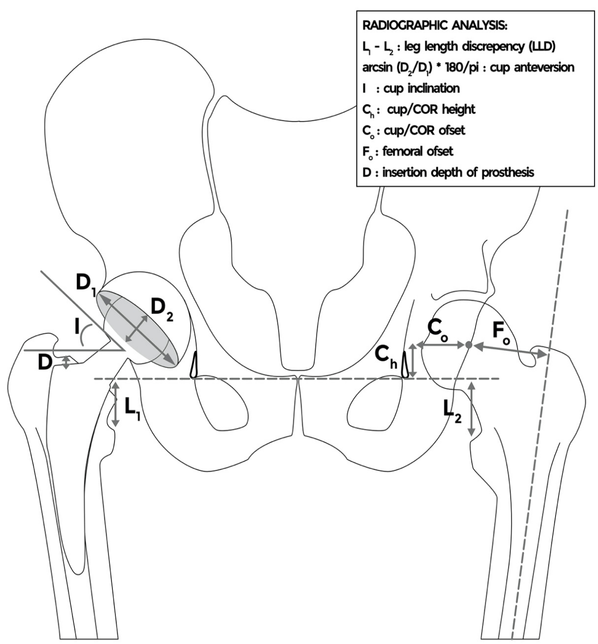

Figure 2. — Radiographic evaluation.

shoulder of the prosthesis to the lateral and superior part of the femoral neck (Fig. 1).

The postoperative radiographic inclination was measured as described by Lewinnek *(9)* as the angle between the teardrop line and the long axis of the acetabular cup on an AP Pelvis X Ray. To calculate anteversion, a postoperative radiograph was loaded in Affinity Designer (Serif Ltd, Nottingham, England) and the oval projection of the face of the cup was recreated with a transparent oval shape. Anteversion was calculated as arcsin (short axis/ long axis) *(9)*.

Functional assessments

Patient reported outcome scores were collected preoperatively and at 1 and 3 months after the operation with the use of a patient generated WOMAC *(10)* and HOOS *(11)* score.

In a subset of 46 patients, the following set of OARSI *(12, 13)* recommended performance based measurements were scored: the 30-second chair stand test (30s CST), the 4 × 10 m fast-paced walk test (40 m FPWT) the 100m fast paced walk test (100m FPWT) and a 9 step stair climb test (9S SCT) *(10)*. These measurements were scored by a trained physiotherapist one week before surgery and at 1 and 3 months after the operation. In addition, a single leg balance test was used to assess postural and balance control of these patients. A patient was scored from 1 to 4 for assisted single stance with a horizontal bar (1), unassisted stance on the operated leg (2), single stance with the ability to bend the leg to 30° (3) and finally the ability to perform a small jump (4).

Patient Rated Outcome

Normality tests were performed using the Shapiro-Wilk test. As all data had a normal distribution, the paired T-test was used to evaluate the differences between preoperative data and the evaluation at 1 and 3 months postoperative. The Wilcoxon test was used for the analysis of the ordinal data. Statistical analysis was performed using SPSS statistical program version 20 (IBM, US). The level of significance was set at 0.05.

Statistical analysis

The patient is positioned in the lateral decubitus, as anterior on the OR-table as possible with dual anterior support on the SIAS and a posterior sacral support to stabilize the pelvis. The leg is positioned in 45° of flexion, slight adduction and 20° of internal rotation. A mayo table supports the foot and ankle.

Surgical technique

The skin is incised in line with the femur, starting at the tip of the greater trochanter, for a length of 8 to 15 cm. Subcutis and the gluteus maximus is split along its fibers, avoiding violation of the fascia and bursa of the greater trochanter. A Charnley retractor spreads the fibers of the gluteus maximus. The interval between gluteus minimus, piriformis and internal obturator tendon is exposed. An anterior retractor is placed between the gluteus medius and gluteus minimus. An incision is made in the capsule, immediately posterior to the piriformis, effectively releasing the capsule and femoral insertion of the internal obturator tendon. A stay suture is placed through capsule and internal obturator tendon. A second neck retractor is placed inside the capsule along the posterior neck. The anterior retractor is

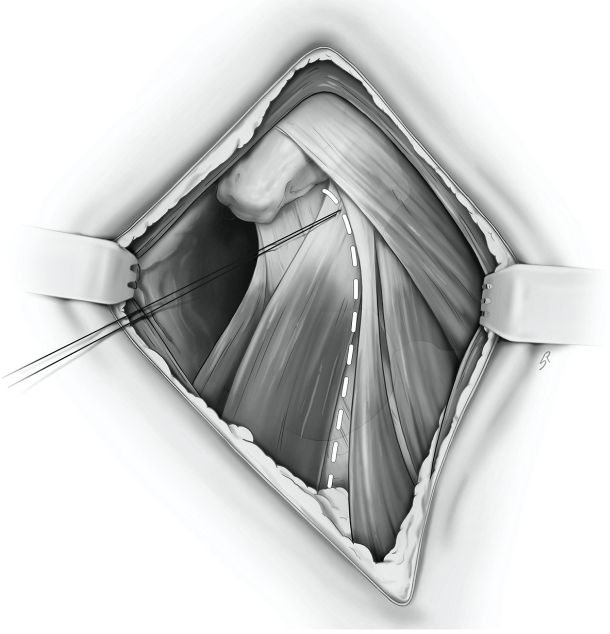

Figure 3. — Surgical interval.

repositioned inside the capsule along the anterior neck. This exposes the fossa piriformis (Fig. 3).

The lateral and superior part of the femoral neck is exposed at the base of the greater trochanter. Bleeding branches of the ascending branch of the medial femoral artery are coagulated. A sharp femoral canal reamer is advanced from the fossa piriformis in the direction of femoral shaft. A second femoral reamer is used to broaden the entry point.

Anteversion is checked, and internal rotation of the leg is adjusted by altering the height of the mayo stand. A small rectangular box chisel is used to open femoral neck and head as to mark the desired anteversion. Neck cut is performed with or without a guidance device, or an adapted broach with a flat cutting surface. The depth of insertion is measured from the anterior and horizontal part of the femoral neck, which is visible both on the preoperative template and during surgery. The head is removed with a corkscrew.

An anterior acetabular retractor is placed over the anterior border of acetabulum (10L /2R o'clock position). The superior acetabulum is exposed with a pin at the 12 o'clock position. A second Charnley pin is placed at the 3L / 9R o'clock position. The inferior retractor is positioned postero-inferior behind the posterior horn of the acetabulum. A superior and circumferential view of the acetabulum is obtained. Adequate view of transverse ligament and acetabular rim should be achieved. Reamers with a curved reamer handle and a curved acetabular impactor are mandatory. The trial cup is used to check cup anteversion and inclination. The transvers acetabular ligament guides for anteversion. Inclination is checked with the impactor guide and comparing templated and intra-operative position of the cup in relation to the acetabular rim at the 12° clock position.

The assistant pushes the leg in a posterior direction, with the knee in adduction and the leg in 20-30° of internal rotation. This brings the neck at the posterior-superior edge of the acetabulum. A gluteus medius retractor and a femoral elevator are used to expose the entry of the femoral canal. Excessive internal rotation should be avoided as this will bring the external obturator tendon under tension, blocking the entrance of the femoral canal. Standard femoral broaching is now possible. After assembly of a trial prosthesis, the hip can be reduced by lifting the femur with a bone hook and an axial push/pull, whilst avoiding excessive internal rotation, for clinical and fluoroscopic control. The hip is dislocated by femoral traction and lifting the head out of the acetabulum, not with internal rotation. Final implantation and reduction is performed.

The capsule is closed with a running suture. The tendon of the internal obturator can be sutured back into its anatomical position which forms a conjoined tendon with the piriformis tendon. After removal of the Charnley frame, the gluteus maximus closes spontaneously. Final approximation is done with a running suture through the thin fascia on top of the gluteus maximus muscle. No drain is used and fat, subcutis and skin are closed.

There are no postoperative restrictions and with this approach hip stability is preserved. Rehabilitation is started as soon as motor function has recovered, in the recovery room or on the ward.

RESULTS

The described operative technique was used in 41 male (one bilateral) and 39 female patients. In 49 cases a short stem cementless implant was used (Fitmore, Zimmer-Biomet, Warsaw), in 32 cases a polished tapered cemented stem was used (Exeter, Stryker, Michigan). A cementless cup (G7 Zimmer-Biomet, Warsaw or Tritanium, Stryker, Michigan) was used in all cases. The mean operation time was 65 minutes (range 40 to 90 minutes).

Clinical results and complications: The mean age at surgery was 67 years (range 47 to 92, sd 9,2). The mean weigh was 79kg (53 to 143, sd 18,14). The mean BMI was 27.5 (range 19.6 to 44.1, sd 5). The median length of stay was 3 days. Mean pre-operative Hb was 14.35 g/dl and dropped to 11.95 g/dl the day after the operation. None of the patients required blood transfusion. There were no major complications. There were no fractures, no infections and no dislocations. One patient (bilateral case) developed Brooker Grade III calcifications (OCD-10 M61559, Clavien-Dindo II). Another patient developed a persistent iliopsoas irritation (OCD-10 M65852, Clavien-Dindo III) for which an arthroscopic release was performed.

Radiographical results: There was a mean leg length discrepancy of + 0.6mm on the operated site (SD 3.5mm, range -8 to +10mm). The center of rotation was on average 4.5mm more medial (SD 3.4 range 11.5 to -4.5 mm) and 4mm more proximal (SD 2.8, range 10 to -5 mm) compared to the native center of rotation.

The change in total hip offset (lateralization) was calculated as the postoperative hip offset minus preoperative offset. The mean lateralization was -0.5mm (SD 3.9mm, range 7.5 to -10 mm).

The difference between planned and final insertion depth of the stem was calculated as the difference between postoperative minus preoperative insertion depth (effective stem lengthening). The mean difference was 1.8mm (SD 3.3mm, range 11 to -7.5 mm).

The postoperative radiographic inclination was 42° (SD 4°, range 31° to 56°) and the radiographic anteversion was 14.5° (SD 4.4°, range 5° to 24.5°). There were 2 cups outside the safe zone of Lewinnek (56/23 &51/14) (Fig 2.).

Patient reported outcome** (Table I)**: The average WOMAC scores preoperatively was 46 (range 4 to 88.1), 76.15 at 1 month (range 42 to 100) and 86.07 at 3 months (range 46 to 100). The evolution of HOOS scores for pain, symptoms, ADL and Quality were similar, indicating that most of the recovery takes place between the operation and the first clinical assessment (Table I).

Table I. — Proms

	Pre-op	1 month	3 months
Womac	46.01	76.14	86.21
HOOS Adl	43.47	75.06	85.63
HOOS pain	43.13	78.27	88.09
HOOS symptoms	42.17	73.60	81.31
HOOS Qol	24.38	64.68	79,026
HOOS sports	23.75	61.59	73.26

Table II. — Functional tests

	Pre op		1 month		Nr		Significance
30s sit to stand test	m = 9 (range 4-14)		m= 11 (range 5-17)		46	better	<0,001
40m fast paced walk test	35,582	1,12m/s	35,412	1,13m/s	46	better	0,192
9 step stair test	17,7422	17,74s	17,9604	17,96s	46	worse	0,87
100m fast pace walk test	80,353	1,24m/s	81,3941	1,13m/s	46	worse	0,005
Single leg balance test	3,15 (m:3)		2,83 (m:3)		46	worse	0,024
	Pre op		3 month		Nr		Significance
30s sit to stand test	m = 9 (range 4-14)		m= 13 (range 8-18)		41	better	<0,001
40m fast paced walk test	35,4601	1,13m/s	28,351	1,41m/s	41	better	0,117
9 step stair test	17,1332	17,13s	11,9368	11,94s	41	better	0,00
100m fast pace walk test	79,5671	1,16m/s	67,2176	1,48m/s	41	better	0,036
Single leg balance test	3,15 (m:3)		3,29 (3)		41	better	0,243

***Functional outcome** (Table II):* One month postoperatively, the 30 CST was significantly better, while the SLBT, the 100m FPWT and the 9 step stair test were significantly worse. The 40m FPWT was better, but this was not statistically significant. At 3 months all test results were better than the pre-operative measurements. However, for the 40m FPWT and the SLBT the difference was not significant.

DISCUSSION

In this study we explore the feasibility of a superior approach to the hip with in situ preparation of the femoral stem, with the use of standard instruments in total hip arthroplasty surgery. Changes in surgical technique are mainly driven by the desire to enhance early clinical outcome but should also reduce complications whilst increasing accuracy of implant position. There is only a small margin for improvement. The technique of a superior in situ approach has previously been described and mainly used in association with a specific implant design or a specific set of instruments *(4, 5)*. In this study, we evaluate the use of an implant independent approach. We assessed the feasibility but also its potential to aid the biomechanical reconstruction of the hip joint.

The muscle interval is situated between piriformis and obturator. The piriformis can be spared and retracted anteriorly *(14, 15)*. The internal obturator has a more posterior fulcrum (ramus inferior of the ischium) and it forms a conjoint tendon with the piriformis *(16,17)*. If not released, its origin will be severely damaged during femoral preparation and standard reduction can be challenging if non modular stems are used. We therefore prefer a release of the internal obturator from the conjoint tendon and perform an anatomical reinsertion at the end of the operation. The external obturator is kept intact and should be protected in order to improve stability.

There is no safe zone for a posterior approach *(9, 18)*. In our study however, there were no dislocations. The preservation of the external obturator and piriformis, the anatomical closure of the capsule, an accurate orientation of stem and cup, and an adequate reconstruction of length and offset may all play its role in the prevention of dislocations.

The ability to start preparing the femoral stem before cutting the femoral neck offers a unique advantage. This specific step in the procedure sets it apart from other minimally invasive hip approaches. There is limited access to the tip of the lesser and greater trochanter but the superolateral part of the femoral neck and the intact femoral head are accessible. The insertion depth is calculated on preoperative templates and the broach is advanced to the predefined depth. Traditional broaches have the disadvantage of a male connection at the proximal part of the broach, which makes them impossible to use as a saw guide. The neck can be cut in a freehand technique. As an alternative, a broach with a female connection can be used as a cutting guide. The neck is cut with a small saw blade over the flat surface of the broach.

Cup implantation is accomplished with curved instruments. The view from a standard posterior approach is perpendicular to the face of the cup. This makes it rather difficult to detect small changes in anteversion/ inclination. A view from above might offer the advantage to be more sensitive for cup position. Most of the cups in this study had an orientation within the safe zone of Lewinnek *(9)*.

Length and offset are generally well controlled. The final cup position was more medial by 4.5mm (SD 3.96) and more proximal by 4mm (SD 2.8mm).

Table III. — Outcome

	Pre-op		1 month		3 months	6 months
	curent study	Am J Phys	current study	Am J Phys	current study	Am J Phys
9 step SCT	17,14	14,84	18,26	21,56	11,94	11,21
HOOS ADL	43,47	54,22	75,06	74,68	85,63	93,16
HOOS pain	43,13	51,74	78,27	78,04	88,09	89,67

On the femoral side the average offset changed by -0.5mm and length by 0.6mm. outliers were within an acceptable range of 1cm. The planned position of the cup however slightly underestimated the final translation of the center of rotation. This may be a consequence of the reaming technique in which the surgeon starts with small reamer to expose the floor of the acetabulum *(19, 20, 21)*.

There is a typical disparity between changes in HOOS and functional performance that suggest that patients may overestimate their functional capacity early after THP (22). Functional tests are a more critical indicator of early postoperative function. The functional results in our study suggest a favorable outcome (Table III).

There are limitations to the technique. It is not suitable to every patient. Severe deformity may require extensive releases and an enhanced exposure. Hip resurfacing surgery cannot be done without dislocation of the femoral head out of the socket. Obesity on the contrary is only a relative contra-indication. The skin incision can be extended and a Charnley frame with deeper blades is a great help in these cases.

The strength of this study is that it represents a single surgeon experience of a consecutive series of unselected patients. A comprehensive range of clinical, functional and radiographic parameters were used to assess the outcome. Overall, the technique can be safely used for most patients eligible for hip replacement.

There are several limitations to this study that should be considered when interpreting these results. The radiographic analysis has been performed by the same surgeon that performed hip surgery. This may induce a bias. Radiological analysis was based on plain radiographs, which are less accurate than Ct scans. This study does not represent the learning curve and also lacks a control group. The functional evaluations were scored by independent physiotherapists who were blinded to the surgical technique. There was a limited capacity to test these patients and only a subset of 39 patients were tested.

Although short term outcome looks promising, long term results still need to be determined.

In conclusion, superior in situ hip replacement is a safe and reproducible surgical technique for conventional total hip replacement. It is less invasive than a traditional posterior approach and is implant independent. It offers the possibility to prepare the femur with reference to the intact femoral anatomy. Clinical and radiographic outcome is satisfactory. Further investigations should be directed to develop instruments for a more accurate femoral reconstruction based on the femoral anatomy.

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