Acta Orthop. Belg., 2016, **82**, 240 -248

ORIGINAL STUDY

Direct anterior approach versus posterolateral approach in total hip arthroplasty : one surgeon, two approaches

Bas Fransen, Marco Hoozemans, Stan Vos

Centre for Orthopaedic Research Alkmaar, Medical Centre Alkmaar, The Netherlands

Early research shows several advantages of the Direct Anterior Approach (DAA) in total hip arthroplasty (THA), although no studies evaluated the DAA on a regular operating table without using fluoroscopy. We performed a retrospective cohort study on the outcome of this variation of the DAA compared with the posterolateral approach (PLA) with one year follow-up. All procedures were uncemented THA performed in 2012 by a single surgeon.

Patients in the DAA group (N = 45) had a lower Body Mass Index ($p < .001$) than the PLA group (N = 38). Functional outcome, pain scores and complications were comparable between the two approaches. Compared with PLA, the DAA was associated with longer operation time ($p < 0.001$), more blood loss ($p < 0.001$), shorter length of stay ($p = .009$), and more adequate acetabular cup inclination ($p = .004$). This study shows that the DAA on a regular operating table without using fluoroscopy has several advantages compared to the PLA.

Keywords : direct anterior approach ; posterolateral approach ; surgical technique ; total hip arthroplasty.

INTRODUCTION

Total hip arthroplasty (THA) is one of the most commonly performed orthopaedic surgical procedures. In the Netherlands about 25.000 hip replacements are performed each year and this number is expected to increase to 50.000 in 2030 (*17*). This is due to changes in population structure, better long-term results of hip replacements and a more active lifestyle in older adults (*17*). To accommodate this increase, more and more attention is given to minimally invasive surgery (MIS) techniques. MIS is aimed at minimizing local soft-tissue trauma and shortening of hospital stay and rehabilitation time (*4,9,18*). The most promising MIS technique in THA is the direct anterior approach (DAA). The DAA was first described by Smith-Petersen in 1949 (*23*), and by Judet and O'Brien in the 1950s, who named it the Hueter approach (*11,16*). Because no muscles are detached, the DAA causes less soft tissue damage compared with the standard posterolateral approach (PLA) where several muscles have to be detached to reach the hip joint (*1,3,4,9*). The reduction in soft tissue damage can be expected to result in less pain after surgery and therefore faster

■ Bas Fransen[1], MD, Orthopaedic resident.
■ Marco Hoozemans[2], Assistant professor.
■ Stan Vos[1], Orthopaedic Surgeon.

[1]*CORAL (Centre for Orthopaedic Research Alkmaar), Medical Centre Alkmaar, The Netherlands.*

[2]*Assistant professor, MOVE Research Institute, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands.*

Correspondence : Bas L. Fransen, Centre for Orthopaedic Research Alkmaar, Wilhelminalaan 12-038, 1815 JD Alkmaar, The Netherlands. E-mail : b.l.fransen@mca.nl

No benefits or funds were received in support of this study. The authors report no conflict of interests.

rehabilitation (*14*). This may result in higher patient satisfaction and quality of life in patients operated with the DAA (*21*).

Even though there is evidence that the DAA has advantages over the PLA (*2*), the anterolateral (*21*), and the direct lateral approach (*8*), there is no definitive proof which technique is to be preferred. It has even been argued that the DAA is associated with more complications, especially in the learning phase (*25*). An important feature of the studies that have made the comparison between the DAA and PLA before, is that DAA is often used with a fracture table and fluoroscopy, in contrast to the PLA, which could bias the results (*26*). The aim of this study was therefore to retrospectively compare the DAA without fluoroscopy and using a regular operating table with the PLA in patients who underwent uncemented THA by a single surgeon. We investigated whether the DAA was associated with better outcome, less pain and a higher rate of complications. Additionally, we compared surgical and radiological outcomes.

MATERIALS AND METHODS

Study design and study population

We conducted a retrospective cohort study in a large volume non-university hospital. The files of patients who underwent a primary total hip arthroplasty between 01-01-2012 and 31-12-2012, performed by a single orthopaedic surgeon, were requested for analysis in January 2014. The surgeon was experienced and had performed 120 PLA and 80 DAA procedures prior to 2012. This time period was chosen because, starting in 2012, surgery and rehabilitation protocols were standardized independent of approach, and to ensure the presence of follow-up data of at least one year after surgery. Patients under 18 years, patients who received a cemented total hip prosthesis, or in whom placement of the prosthesis was part of revision surgery, were excluded.

Surgical procedure

For the DAA, the patient is placed in a supine position. The procedure was performed on a regular operating table and no fluoroscopy was used. An incision was made 2-3 cm distal and 2-3 cm lateral of the anterior superior iliac spine, to prevent damage to the lateral cutaneous femoral nerve. The femoral head was reached utilizing the internervous plane that is present between the sartorius and tensor fascia latae superficially and between the rectus femoris and gluteus medius more profoundly. For the PLA, the patient is placed in the lateral position. The femoral head is reached after incisions in the tensor fascia latae and gluteal fascia, after bluntly dividing the gluteus maximus and after releasing insertions of the piriformis, gemeli and obturator externus tendons. For all operations, and therefore for both approaches, the same hip prosthesis (Corail Hip System, DePuy Synthes, Warsaw, Indiana, United States of America) was used. All three types of stem were available (High offset, standard and coxa vara) and in all patients the Pinnacle cup system was implanted.

Descriptive data

The patient characteristics (Table I) and operative variables were collected from patients' files and included age, gender, Body Mass Index (BMI), stature, bodyweight American Society of Anaesthesiologists (ASA) classification and type of anaesthesia for all patients.

Primary outcome measures

All outcome variables were registered at the regular patient visits before surgery and at one year follow-up. Functional outcome parameters were range of motion of the hip (endorotation and flexion) and daily function measured with the Harris Hip Score (HHS) (*24*). In the HHS, scores range from 0 to 100 with lower scores indicating a worse hip function in daily life. The clinical outcome variables were perceived pain at the moment of assessment, assessed using a Visual Analogue Scale (VAS) (*5*) (0-10 cm, 0 cm indicating no pain, 10 cm extreme pain). Complications up to one year after surgery were registered.

Secondary outcome measures

Surgical outcome parameters were operation time and blood loss during the operation. The length of stay (LOS) in the hospital after surgery was retrieved from the hospital's registration system. Radiological outcome was evaluated by assessing the standard pelvic anterior-posterior X-rays that were made pre-surgery and at six weeks follow-up. Limb length discrepancy (LLD), acetabular cup inclination and femoral stem positioning were measured. LLD was categorised as -2 (extensive shortening of affected limb), -1 (minor shortening of affected limb),

Table I. — Patient characteristics and operative variables

	PLA Mean (SD)	Min-Max	DAA Mean (SD)	Min-Max	*p*-value
Patient characteristics					
Age (years)	62.6 (9.2)	42-81	64.2 (8.5)	39-78	.424
Gender	Male	N = 13 (37.1%)	Male	N = 15 (33.3%)	.723
	Female	N = 22 (62.9%)	Female	N = 30 (66.7%)	
Stature (cm)	174.2 (9.4)	160-200	172.2 (8.9)	157-192	.325
BMI	27.6 (3.2)	20.9-36.9	25 (2.8)	19.8-31.5	<.001
Operative variables					
Side	Left	N = 18 (47.4%)	Left	N = 15 (33.3%)	.193
	Right	N = 20 (52.6%)	Right	N = 30 (66.7%)	
ASA classification	1	N = 16 (42.2%)	1	N = 24 (53.3%)	.598
	2	N = 20 (52.6%)	2	N = 19 (42.2%)	
	3	N = 1 (2.6%)	3	N = 2 (4.5%)	
	Unknown	N = 1 (2.6%)			
Anesthesia	Spinal	N = 23 (60.5%)	Spinal	N = 26 (57.8%)	.800
	General	N = 15 (39.5%)	General	N = 19 (42.2%)	

SD = standard deviation ; BMI = body mass index ; ASA = American Society of Anesthesiologists.

none, +1 (minor lengthening of affected limb) or +2 (extensive lengthening of affected limb). Cup inclination was measured using the angle of the cup in relation to the transischial line. An inclination between 30 and 50 degrees was considered adequate, and both the inclination and whether this was adequate were registered (*10*). Stem position was classified as minor valgus, minor varus or neutral.

Statistical analysis

Statistical analyses were performed using SPSS Statistics, version 20 (IBM Corporation, Armonk, NY, USA). Normality of continuous variables was assessed using histograms, q-q plots, box-plots, Kolmogorov-Smirnov tests and z-values for skewness and kurtosis. Differences (Δ) in change in outcome variables from presurgery to one-year follow-up were also calculated. To test for differences between DAA and PLA for all continuous outcome measures, independent samples T-tests were used for normally distributed variables or non-parametric Mann-Whitney U tests if parametric assumptions were violated. Chi-squared tests were performed for categorical variables. Because almost all functional variables were skewed, non-parametric Mann-Whitney U tests were performed to test for differences between DAA and PLA for all functional variables to ensure proper statistical analysis. The patient characteristics and Δ scores were normally distributed. A $p < .05$ was considered significant.

RESULTS

Patient characteristics and operative variables

A total of 80 patients (83 hips) were included. Patient characteristics are shown in Table I. Thirty-eight procedures were done using the PLA and 45 procedures using the DAA. The three patients who underwent a THA on both sides had the same approach (PLA) used in both surgeries. No patients received a bilateral THA in a single session. Patients in the PLA group had a significantly higher Body Mass Index (BMI) compared to patients in the DAA group ($p < .001$). Both groups were comparable when looking at ASA classification, side operated on and the type of anaesthesia that was used.

Table II. — Primary outcome measurements

	Pre-surgery			1 year follow-up			Delta scores		
	Median (IQR)		*p*-value	Median (IQR)		*p*-value	Mean (SD)		*p*-value
	PLA	DAA		PLA	DAA		PLA	DAA	
VAS	4.9 (3)	5.2 (4)	.677	0 (0)	0 (1)	.773	-4.3 (2.5)	-4.2 (2.4)	.874
HHS	57.5 (19)	62 (16)	.103	97 (6)	96.5 (6)	.072	36.5 (13.5)	35.1 (11.6)	.656
Flexion (degrees)	90 (10)	90 (10)	.906	95 (10)	100 (15)	.070	7.3 (16.8)	8.2 (12.8)	.797
Endorotation (degrees)	0 (5)	0 (5)	.895	10 (10)	15 (9)	.811	10.2 (8.9)	10.4 (6.7)	.896

IQR = Interquartile range ; VAS = Visual Analogue Scale ; HHS = Harris Hip Score.

Primary outcome variables

Functional outcome

There were no significant differences between the DAA and PLA group in pre-surgery assessment of the HHS and range of hip motion (Table II). At 1 year follow-up, no differences in functional parameters were found between groups. Seven patients in the PLA group and 9 patients in the DAA group were lost to follow-up because of a no-show at their 1 year post-surgery appointment. The difference (Δ) between the pre-surgery measurements of the HHS and range of motion and the measurements at 1 year follow-up was also calculated. The increase in function measured with these scores did not differ significantly between the two approaches.

Pain

The groups were comparable in pre-surgery and one year post-operative VAS scores (Table II). The decrease (Δ) in pain was comparable between both groups.

Complications

All complications are detailed in Table III. No serious adverse events, which were prosthetic joint infections or deaths, were observed in either group. In both groups there was one minor complication during surgery. One patient was admitted to the medium care unit after developing symptoms of adrenal insufficiency. In both groups there was one complication requiring additional surgery : a superficial wound infection and the removal of a broken-off fragment of a drain in the PLA and DAA group, respectively.

Secondary outcome variables

Surgical outcome

Operation time using the DAA was significantly longer (Fig. 1), with a median duration of 55 minutes (IQR 10, min-max 45-90) for the PLA group and a median duration of 75 minutes (IQR 23, min-max 51-180) for the DAA group ($p < .001$). Patients operated with the PLA had a median of 300 millilitres (IQR 144, min-max 125-900) blood loss (Fig. 2), whereas patients operated using the DAA had a median blood loss of 450 millilitres (IQR 250, min-max 150-3000), which was significantly more ($p < .001$).

LOS

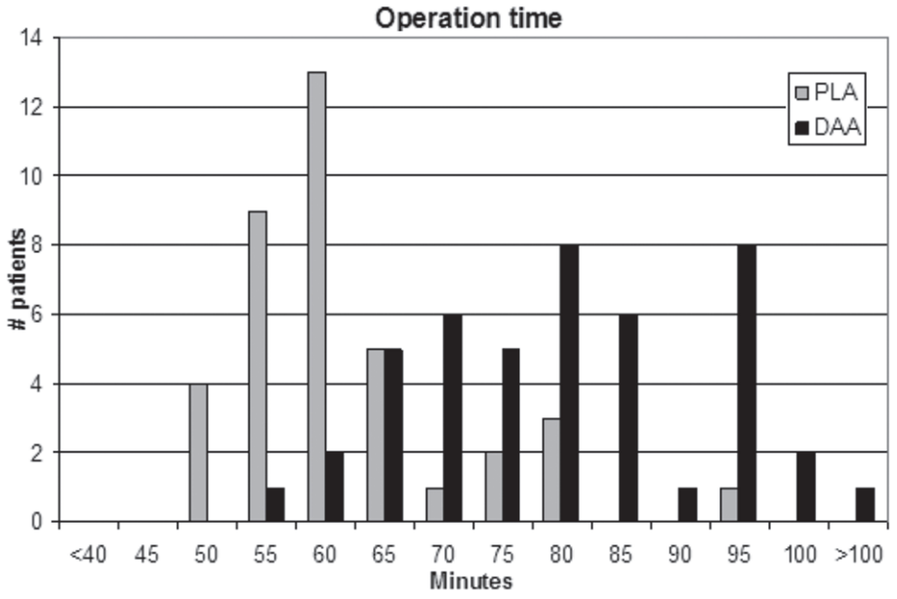
Median LOS in the DAA group was 4 days (IQR 1, min-max 3-8) compared to 4 days (IQR 1, min-max 3-16) in the PLA group, which was significantly longer for the PLA group ($p = .009$).

Radiological outcome

No extensive lengthening or shortening of the leg was recorded in either group. Five patients in the PLA group and 6 in the DAA group had a minor LLD. Cup inclination was significantly larger in the PLA group ($p = .004$). None of the patients had an inclination of 30 degrees or less. Six patients in the PLA group had a cup inclination of 50 degrees or more, compared with two patients in the DAA

Table III. — Complications

	PLA	DAA
Surgery	1× fissure of calcar without consequence	1× heavy ossal bleeding
Post-surgery	1× post-operative anemia requiring transfusion	1× post-operative anemia requiring transfusion
	1× admitted to medium care because of adrenal insufficiency	1× re-surgery after 1 day to remove fragment of drain
		1× urine retention requiring CAD for 6 weeks
During follow-up	1× superficial wound infection requiring surgical debridement	1× disabilitating hematoma in leg for several weeks
	1× sensation of leg length discrepancy	2× persisting pain upper leg, 1 requiring block of n. cutaneus fem. lat. and 1 requiring NSAID treatment
		1× temporary suspicion of psoas tendinitis
Total	5	8



PLA = posterolateral approach, DAA = direct anterior approach.

Fig. 1. — Duration of the operation in minutes

group. Stem position was comparable between both groups, with about one quarter of the stems positioned in varus and none in valgus (Table IV).

DISCUSSION

The aim of this study was to compare differences in relevant outcomes between the DAA and the PLA in patients undergoing THA by a single surgeon. Patients in the DAA group were able to leave the hospital earlier and had similar pain scores and functional results at one year after surgery. The DAA also resulted in better acetabular cup positioning, but the PLA group had shorter operation time and less blood loss during the operation.

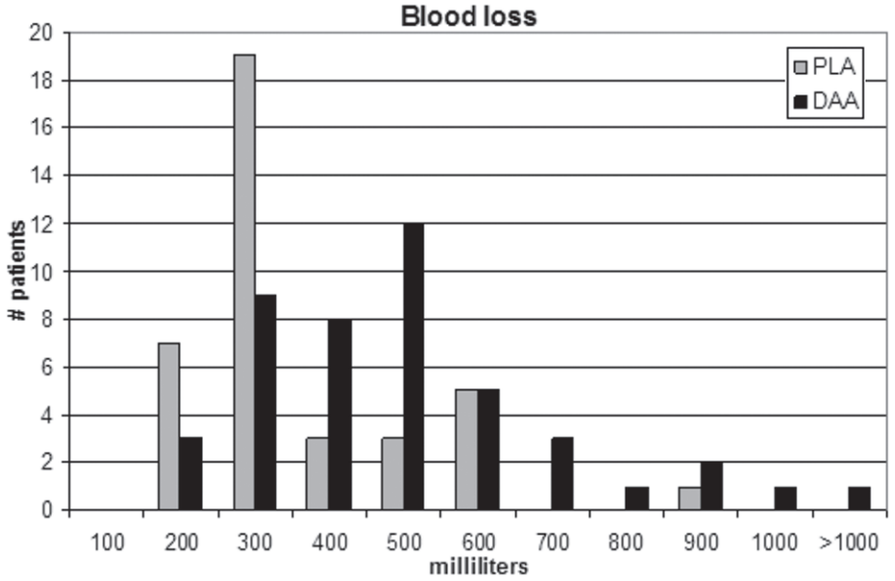
Patient characteristics and operative variables

The outcomes of 80 patients undergoing 83 THA procedures were analysed. Only patients that

Table IV. — Radiological outcome

Radiological outcome	PLA		DAA		*p*-value
	Mean (SD)	Min-Max	Mean (SD)	Min-Max	
Inclination (degrees)	45.8 (4.5)	39-56	42.7 (5.0)	34-60	.004
Limb Length Discrepancy	-1	N = 1 (2.6%)	-1	N = 3 (6.7%)	.589
	None	N = 33 (86.9%)	None	N = 39 (86.6%)	
	1	N = 4 (10.5%)	1	N = 3 (6.7%)	
Stem position	Minor Varus	N = 10 (26.3%)	Minor Varus	N = 12 (26.7%)	.971
	Neutral	N = 28 (73.7%)	Neutral	N = 33 (73.3%)	
	Minor Valgus	N = 0 (0.0%)	Minor Valgus	N = 0 (0.0%)	

SD = standard deviation.



PLA = posterolateral approach, DAA = direct anterior approach.

Fig. 2. — Per-operative blood loss in millilitres

received an uncemented total hip prosthesis were included, because DAA was only used for uncemented prostheses during the period examined. Potential bias of results was further reduced by analysing a single surgeon cohort ensuring a similar surgical technique, clinical situation and rehabilitation protocol in all patients. There was a significant difference in the BMI of patients between the DAA and PLA group. The resident or surgeon who chose the approach that was going to be used during an outpatient clinic visit could have gone for the more trusted option of the PLA when confronted with an obese patient. Furthermore, patients who are more active in daily life would sooner opt for the DAA, because they want to be able to be mobile sooner. A study by Hallert *et al* found that a higher BMI can influence operation time when using the DAA, but this is mostly relevant in morbidly obese patients (*9*). However, it could be that the higher BMI in the DAA group compared to the PLA would have influenced the results with respect to the operation time. We therefore performed an additional analysis using

a linear regression model to see whether operation time was influenced by BMI. We divided patients into being overweight or not (BMI > 25). When correcting for the effect of approach on operation time, this showed that patients that were overweight had an average operation time that was 8 minutes longer (p = .030).

Primary outcome variables

Functional outcome

There are indications in literature that the DAA results in a faster recovery time (*26*), improvement in a large number of gait parameters (*14,15*), a slightly better stair climbing ability (*12*), a higher mobilization status (*21*) and a more rapid recovery of hip function (*13,15,20*) in the short term. When looking at the 1 year follow-up measurements and the Δ scores in the current study, there was no difference in function between both groups despite the earlier discharge from hospital. This might indicate that the short-term benefits of the DAA above the PLA found in other studies, disappear after the period of one year.

Pain

No significant differences in pain scores were registered between the DAA and PLA groups before or at one year after surgery. The decrease in pain experienced was also comparable between groups. Our post surgery pain scores were taken one year after the operation. There are indications that in the short term (6-12 weeks after surgery) the DAA is associated with less postoperative pain and consumption of pain medication (*8,21*), which supports the notion from the functional results that the benefits of the DAA are mostly visible in the first months after the surgery.

Complications

Complications rates and severity of complications were comparable between both groups in the current study, despite earlier research suggesting that the DAA resulted in more complications (*25*). It is currently unclear whether the experience of the surgeon could have influenced in the complication rate, or whether this is due to the differences in use of fluoroscopy and/or a fracture table. It would be of interest to further investigate whether these different aspects could influence the complication rate when using the DAA.

Secondary outcome variables

Surgical outcome

Operation time and blood loss were significantly less in patients operated using the PLA. One patient in the DAA group had an operation time of 180 minutes and 3 litres blood loss, because of heavy osseous bleeding during the procedure. Even when this patient was not included in analysis, groups remained significantly different. There have been several other studies that have shown a significantly longer operation time and more blood loss when using the DAA (*6,25*). Different results were reported by Alecci *et al*, who found no significant difference in blood loss and operation time in a cohort of 419 patients comparing the DAA with the direct lateral approach (*1*).

LOS

The DAA group had a significantly shorter LOS, which indicates that patients reached satisfactory mobility earlier than the PLA group. This is consistent with findings in other studies (*1,6,8*). A shorter LOS is also associated with lower costs when looking at overhead and staff costs (*22*). Together with the assumption that DAA is associated with better mobility and therefore possibly less medical help (e.g. physical therapy and medication), this suggests that the DAA might be more cost-effective than the PLA.

Radiological outcome

It is known that the positioning of the femoral and acetabular components can influence the number of revisions and survival of the prosthesis (*10*). Cup placement with the DAA has been proven adequate (*7*). To our knowledge, no study has compared cup positioning in the DAA without the use of an orthopaedic table or fluoroscopy with other approaches. We found a significantly lower

cup inclination in the DAA group, with a 3 times higher number of patients with an inadequate angle of inclination in the PLA group. This indicates that the longevity of the prosthesis is expected to be greater in patients operated with the DAA. No difference was found between the DAA and PLA in LLD or femoral stem positioning.

Limitations

There are several limitations to this study. We collected data on a single surgeon in a single hospital. A prospective multicentre study with several experienced surgeons could provide stronger evidence on the advantages and disadvantages of the DAA. In the present study, patients in the DAA group were significantly less heavy than patients in the PLA group, which could have biased the comparability of the groups. Furthermore, since the DAA had only been used for one year with a regular operating table and without fluoroscopy in our hospital, we were only able to collect data at 1 year follow-up. A longer follow-up period would provide clues to whether there was a difference in placement of the components of the prosthesis, since this would result in different revision rates. Despite these limitations, the results of this study provide sufficient foundation for further research.

CONCLUSION

We performed a retrospective cohort study of patients that received an uncemented THA using either the PLA or the DAA by a single experienced surgeon with a follow-up of one year. Our results showed that patients operated using the DAA were able to leave the hospital earlier. Cup-placement was superior in the DAA group, which is important for the longevity of the implant. Complication rates and function after one year are comparable, although blood loss and operation time were less in the PLA group. Our study is the first to compare DAA without fluoroscopy on a regular operating table and shows that the DAA should be considered in THA compared with the PLA when looking at the midterm results. To further compare the DAA and PLA in uncemented THA we are currently in the progress of starting a randomised controlled clinical trial.

REFERENCES

1. **Alecci V, Valente M, Crucil M *et al.*** Comparison of primary total hip replacements performed with a direct anterior approach versus the standard lateral approach : perioperative findings. *J Orthop Traumatol* 2011 ; 12 (3) : 123-129.
2. **Barrett WP, Turner SE, Leopold JP.** Prospective randomized study of direct anterior vs postero-lateral approach for total hip arthroplasty. *J Arthroplasty* 2013 ; 28 : 1634-1638.
3. **Bergin PF, Doppelt JD, Kephart CJ *et al*.** Comparison of minimally invasive direct anterior versus posterior total hip arthroplasty based on inflammation and muscle damage markers. *J Bone Joint Surg Am* 2011 ; 93 (15) : 1392-1398.
4. **Bremer AK, Kalberer F, Pfirrmann CW, Dora C.** Soft-tissue changes in hip abductor muscles and tendons after total hip replacement : comparison between the direct anterior and the transgluteal approaches. *J Bone Joint Surg Br* 2011 ; 93 (7) : 886-889.
5. **Brokelman RB, Haverkamp D, van Loon C *et al*.** The validation of the visual analogue scale for patient satisfaction after total hip arthroplasty. *Eur Orthop Traumatol* 2012 ; 3 : 101-105.
6. **de Verteuil R, Imamura M, Zhu S *et al.*** A systematic review of the clinical effectiveness and cost-effectiveness and economic modelling of minimal incision total hip replacement approaches in the management of arthritic disease of the hip. *Health Technol Assess* 2008 ; iii-iv, ix.
7. **Eilander W, Harris SJ, Henkus HE, Cobb JP, Hogervorst T.** Functional acetabular component position with supine total hip replacement. *Bone Joint J* 2013 ; 95-B : 1326-1331.
8. **Goebel S, Steinert AF, Schillinger J *et al.*** Reduced postoperative pain in total hip arthroplasty after minimal-invasive anterior approach. *Int Orthop* 2012 ; 36 (3) : 491-498.
9. **Hallert O, Li Y, Brismar H, Lindgren U.** The direct anterior approach : initial experience of a minimally invasive technique for total hip arthroplasty. *J Orthop Surg Res* 2012 ; 7 : 17.
10. **Harrison CL, Thomson AI, Cutts S, Rowe PJ, Riches PE.** Research synthesis of recommended acetabular cup orientations for total hip arthroplasty. *J Arthroplasty* 2014 ; 29 : 377-382.
11. **Judet J, Judet R.** The use of an artificial femoral head for arthroplasty of the hip joint. *J Bone Joint Surg Br* 1950 ; 32-B : 166-173.
12. **Lamontagne M, Varin D, Beaule PE.** Does the anterior approach for total hip arthroplasty better restore stair climbing gait mechanics ? *J Orthop Res* 2011 ; 29 (9) : 1412-1417.

13. **Maffiuletti NA, Impellizzeri FM, Widler K *et al.*** Spatiotemporal parameters of gait after total hip replacement : anterior versus posterior approach. *Orthop Clin North Am* 2009 ; 40 (3) : 407-415.
14. **Mayr E, Nogler M, Benedetti MG *et al.*** A prospective randomized assessment of earlier functional recovery in THA patients treated by minimally invasive direct anterior approach : a gait analysis study. *Clin Biomech (Bristol, Avon)* 2009 ; 24 (10) : 812-818.
15. **Nakata K, Nishikawa M, Yamamoto K, Hirota S, Yoshikawa H.** A clinical comparative study of the direct anterior with mini-posterior approach : two consecutive series. *J Arthroplasty* 2009 ; 24 (5) : 698-704.
16. **O'Brien RM.** The technic for insertion of femoral head prosthesis by the straight anterior or Hueter approach. *Clin Orthop* 1955 ; 6 : 22-26.
17. **Otten R, van Roermund PM, Picavet HS.** [Trends in the number of knee and hip arthroplasties : considerably more knee and hip prostheses due to osteoarthritis in 2030] : *Ned Tijdschr Geneeskd* 2010 ; 154 : A1534.
18. **Palan J, Beard DJ, Murray DW, Andrew JG, Nolan J.** Which approach for total hip arthroplasty : anterolateral or posterior ? *Clin Orthop Relat Res* 2009 ; 467 (2) : 473-477.
19. **Pogliacomi F, Paraskevopoulos A, Costantino C, Marenghi P, Ceccarelli F.** Influence of surgical experience in the learning curve of a new approach in hip replacement : anterior mini-invasive vs. standard lateral. *Hip Int* 2012 ; 22 : 555-561.
20. **Reininga IH, Stevens M, Wagenmakers R *et al.*** Comparison of gait in patients following a computer-navigated minimally invasive anterior approach and a conventional posterolateral approach for total hip arthroplasty : A randomized controlled trial. *J Orthop Res* 2013 ; 31 (2) : 288-294.
21. **Renken F, Renken S, Paech A *et al*.** Early functional results after hemiarthroplasty for femoral neck fracture : a randomized comparison between a minimal invasive and a conventional approach. *BMC Musculoskelet Disord* 2012 ; 13 : 141.
22. **Rottger J, Scheller-Kreinsen D, Busse R.** Patient-level hospital costs and length of stay after conventional versus minimally invasive total hip replacement : a propensity-matched analysis. *Value Health* 2012 ; 15 : 999-1004.
23. **Smith-Petersen MN.** Approach to and exposure of the hip joint for mold arthroplasty. *J Bone Joint Surg Am* 1949 ; 31A : 40-46.
24. **Soderman P, Malchau H.** Is the Harris hip score system useful to study the outcome of total hip replacement ? *Clin Orthop Relat Res* 2001 ; 384 : 189-197.
25. **Spaans AJ, van den Hout JA, Bolder SB.** High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. *Acta Orthop* 2012 ; 83 (4) : 342-346.
26. **Sugano N, Takao M, Sakai T *et al*.** Comparison of mini-incision total hip arthroplasty through an anterior approach and a posterior approach using navigation. *Orthop Clin North Am* 2009 ; 40 (3) : 365-370.