



## Direct anterior total hip arthroplasty in supine position using regular OR table : case series and review of complication and reoperation rate

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**Direct anterior approach total hip arthroplasty (DAA-THA) has gained popularity in the last decades due to multiple advantages : reduced blood loss, muscle sparing, reduced pain, reduced dislocation rate, shorter hospital stay and faster recovery. However, initial studies have reported an unacceptable high intra-operative complication rate, especially during the learning curve. The complications and reoperations in a consecutive series of 356 DAA-THA's using a supine positioning on a regular OR table, without femoral hyperextension, were analysed retrospectively. Conclusion : This study could not confirm the previously reported high complication rate in DAA-THA. The supine positioning without femoral hyperextension is a safe technique, little susceptible by the surgeon's learning curve.**

**Keywords :** Minimally invasive surgery ; direct anterior approach ; total hip arthroplasty ; muscle-sparing ; anterior-supine ; complications.

### INTRODUCTION

The Direct Anterior Approach (DAA) to the hip was first introduced by Heuter in 1881, later used by Smith-Petersen in 1917 and first used for arthroplasty techniques in the fifties by the Judet brothers in France (13,33,15). Recently, DAA has gained popularity because of potential advantages including reduced blood loss, less soft-tissue damage, reduced pain, reduced dislocation rate, shorter hospital stay and

faster recovery (21,3,6,23,28,1,22). However, higher rates of complications including periprosthetic fracture, increased blood loss, longer operating time and nerve injury, especially during the early learning phase have been reported (6,23,2,38,14,26,34,20). Therefore DAA total hip arthroplasty (DAA-THA) is surrounded with a lot of debate and controversies. Currently, DAA-THA is roughly performed using two different surgical techniques regarding positioning. Either the surgeon uses an orthopaedic fracture table with traction devices (Medacta table, Hana table, ProFx table, orthopaedic fracture table ...) or a regular table with supine patient positioning is used. The current instrumentation and improvement in surgical technique has made the use of an orthopaedic traction table optional.

Current literature has focused merely on the complications of the traction table and has not compared this data with supine positioning on a regular OR table. However, the importance of comparing these two different techniques has been mentioned earlier (21,23,24,19,7). The aim of this study is to provide data regarding the complication

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and reoperation rate of DAA-THA in supine positioning using a regular OR table without femoral hyperextension.

## METHODS

Data of a consecutive series of 356 primary DAA-THA's in a period between 01/04/2011 and 02/06/2015 were analysed retrospectively. All procedures were done by one surgeon (JL) using a regular OR table and supine positioning, without femoral hyperextension. The anterolateral approach has been the operating surgeon's preferred approach for primary THA, before adopting the DAA technique. The first 356 cases after a radical change in surgical technique were analysed in this study. Exclusion criteria were revisions and hip fracture as the primary indication. The minimum follow-up was one year and no patients were lost to follow-up before the one year mark. During the study period (from 1/1/2016 to 1/1/2017), 90% of patients have attended the orthopaedic clinic for a physical examination and all patients were subjected to a telephone survey. 340 patients (96%) have effectively participated to the telephone survey, reasons for the inability to participate were death (3 patients), dementia, language or speaking difficulties and inability to contact. The follow-up period for the patients who were unable to return to clinic or participate to the telephone survey, was reduced to the last clinic appointment.

Data was collected prospectively and analysed retrospectively. All the complications and reoperations were thoroughly traced and collected from the medical files, the clinical review and a telephone survey. Data was cross-referenced during the telephone survey to assure complete capture of all complications. Directive questions were used during the telephone survey to trace for the possible complications. The telephone survey was conducted by the first author (VV), the clinical review was done by the senior author (JL). Since every patient reviewed in hospital was also rendered to the telephone survey, an extensive cross-checking of results occurred. We found a 98% concordance between clinical review and telephone survey. Inter-observer disagreement was solved by discussion :

1 psoas impingement was added because diagnosis was only recently made, and 1 patient was excluded from the statistical analysis because of contradictory statements during the telephone survey. The study was approved by the local hospital ethics committee and University hospital Antwerp research ethics committee operating according to the ICH/GCP guidelines (registration number B300201627818). An informed consent was obtained by all the patients as required by the ethics committees.

## Surgical technique

The procedure was performed on a regular operation table, in a supine position, without extension devices. The technique is described by Parvizi et al, with minor modifications (25). First, the incision was started more lateral, 4cm lateral and 2cm distal from the anterior superior iliac spine (ASIS), in order to avoid lateral femoral cutaneous nerve (LFCN) injury. This way, the tensor fascia lata perforator was always visible in the anterior half of the incision (30). Second, the superior release, known as the critical step in the access to the femoral canal, was performed in 2 steps. The initial release was done with the hip in situ, before any osteotomy was made. Subsequently, the release was finalised after the femoral head was removed in a classical fashion with the use of a bone hook in the canal. Adopting this 2-step superior release has made head extraction easier and has made a double neck osteotomy redundant. Third, the femoral hyperextension, which could increase the risk of intra-operative complications, such as trochanteric fractures, was excluded. Femoral hyperextension was never applied, arguably because this could blur the perspective to the femoral canal and make correct stem positioning technically more demanding. A double-prong retractor positioned laterally behind the greater trochanter lifting up the femur and a sharp hohmann retractor postero-medially around the calcar were positioned during femoral broaching. Fourth, the medially positioned retractor behind the transverse acetabular ligament was removed during acetabular reaming. Only a double-prong postero-inferior retractor and an antero-superior retractor over the pelvic brim were

positioned during reaming. This way more freedom was created to position the cup in the appropriate abduction angle. Image intensifier guidance during the procedure was never used. The acetabular and femoral components were press-fit, uncemented porous-types with ceramic-on-ceramic or ceramic-on-polyethylene bearings. ZimmerBiomet Allofit and Maxera (monoblock ceramic bearing for large head sizes) cups were implanted and Avenir stems in all cases (Zimmer, Warsaw, IN). Postoperative visits were scheduled at 4 weeks, 3 months and 1 year. All patients had routine postoperative x-rays, standard AP pelvic and lateral views, taken at 4 weeks and 1 year postoperative.

## RESULTS

356 primary DA-THA's in 327 patients, consisting 139 males and 188 females, were included in the study. Mean follow-up period was  $32 \pm 13$  months (12-62 months). Indications for treatment included primary osteoarthritis (316 hips), post traumatic osteoarthritis (5 hips), avascular necrosis (33 hips), dysplasia (2 hips). Staged bilateral procedures were performed in 29 patients. Mean age was 65 years. Right to left hip ratio was 0,58. All implants were uncemented, 44 Maxera cups and 286 Allofit cups. Uncemented Avenir stems were used in all cases (Zimmer, Warsaw, IN). Ceramic-on-ceramic bearing surfaces in 97 THA's (27%) and ceramic-on-polyethylene bearing surfaces in 259 THA's (73%). The complications with according case number are summarised in Table 1. The Intra-operative complication rate was 3,0%. Post-operative complication rate 5,9%. Medical complication rate 1,9%. The dislocation rate was 0,9% (3 patients), with a total of 4 dislocation. Two cup positions of the dislocated hips were outside Lewinnek's safe zon. (18) One open reduction and 3 closed reductions were performed. There were no revisions performed for instability reasons. We recorded 4 post-operative infections (1,2%). Two superficial wound infections were successfully managed with antibiotic suppression. Deep infection rate was 0,6%, 2 cases with deep infection at 3 weeks and 8 weeks were initially teated with DAIR (Debridement Antibiotics Implant Retention),

Table 1.

	N = 356	%
<b>Intra-operative complications</b>	<b>11</b>	<b>3,0%</b>
Femoral nerve neuropraxia	1	0,3
LFCN neuropraxia	5	1,5
LFCN persistent	2	0,6
Loose cup (intraoperative complication, revised)	1	0,3
Neck-cup impingement, symptomatic (cup malposition)	1	0,3
Femoral fracture: Calcar	1	0,3
Femoral fracture: Greater trochanter (>1,5 cm)	0	0
Femoral perforation	0	0
<b>Post-operative complications</b>	<b>21</b>	<b>5,9%</b>
Hematoma	3	0,9
SSI superficial	2	0,6
SSI deep	2	0,6
- Requiring DAIR	2	0,6
- Requiring 2 stage revision during study	2	0,6
Muscle hernia	1	0,3
Dislocation	3 patients (4 events)	0,9
- Closed reduction	3	0,9
- Open reduction	1	0,3
- Requiring revision	0	0,0
Subsidence	1	0,3
Postoperative traumatic periprosthetic fracture Vancouver type B (non-operative treatment)	1	0,3
Leg length discrepancy (> 2cm)	1	0,3
Squeaking	1	0,3
Heterotopic ossification (Brooker grade 1 and 2)	3	0,9
Psoas tendon impingement	3	0,9
<b>Medical complications</b>	<b>7</b>	<b>1,9%</b>
Cardiac problems	2 (AF and HF)	0,6
Cardiac arrest post-operative	1	0,3
DVT/PE (non-fatal)	4	1,2

however requiring 2-stage revision later. Subsidence (>1cm) was found in 1 case, which did not require reintervention. Heterotopic ossification, Brooker grade I and II in 0,9% (1 excision of calcification for functional impairment), no patients with Brooker grade III. One patient was diagnosed with persisting squeaking, this ceramic-on-ceramic hip was a Maxera cup with head size 40mm and was not revised during the study period. Three patients with psoas tendon impingement syndrome were recorded, two arthroscopic psoas tendon releases were performed with complete resolution of symptoms afterwards. One psoas tendon release was pending at the end of the study period. Due to a fall (low-impact trauma) 1 month after surgery, one periprosthetic fracture (Vancouver type B) has occurred, which was treated nonoperatively. The stem was positioned correctly and not undersized. Although the traumatic event was obvious, we realise this fracture might have been the result of an unnoticed intra-operative fracture. Because of this uncertainty,

this complication could have been categorised both as an intra-operative and postoperative complication. Five patients (1,5%) have presented with a clinical neuropraxia of the lateral femoral cutaneous nerve (LFCN), which have resolved over time in. In two patients (0,6%) persistent symptoms of LFCN injury during the study period were noted. 1 calcar fracture has occurred during broaching and was treated conservatively. No significant (>1,5cm) greater trochanter fractures were recorded. 30-day postoperative transfusion rate was 9%. Overall an even distribution of complications among the 356 cases included in the study was found.

The reinterventions are summarised in Table 2. A reintervention rate of 3% (10 cases) and a revision rate of 1,5% (5 cases) was recorded. Two acetabular cup revisions were recorded because of aseptic loosening. One early loosening of the acetabular implant occurred (Maxera cup), which required revision, cup repositioning and conversion to Allofit cup 1 week after primary surgery. A 96% patient satisfaction rate was noted. No obvious downward trend in intra-operative complications, with increasing experience of the surgeon, was recorded.

Table 2.

Revisions	5	1,4%	Case number
Acetabular cup revision	3	0,9	after 42m, 11d, 12m 27, 171, 224
2-stage revision for recurrent infection after DAIR	2	0,6	after failed DAIR 200, 355
<b>Other reoperations</b>	<b>7</b>	<b>1,9%</b>	
DAIR (debride antibiotics implant retention)	2	0,6	at 3w and at 8w 200, 355
Open reduction	1	0,3	at 6 w 230
Excision heterotopic calcification	1	0,3	Brooker 2 and stiffness 195
Muscle hernia closure	1	0,3	after 2m 149
Psoas releases (arthoscopic)	2 (+ 1 pending)	0,6	excessive anterosuperior coverage area 167, 291, (332)

## DISCUSSION

The direct anterior approach (DAA) is widely used for minimally invasive total hip arthroplasty in North America, Europe, and Asia (27). In Belgium and the Netherlands there seems to be a wide experience in DAA-THR surgery and it seems that once the surgeon masters the DAA, he adopts it as his standard approach for primary THA (8,9,11,37). In DAA-THA research, the focus lies on dislocation rate and speed of recovery. But there seems to be little attention for intra-operative complication rate and early revision rate. Intra-operative difficulties may cause complications such as component

malposition or ceramic liner fracture which affects the outcome in the longer term. This case series has demonstrated the complications of the first 356 cases after a radical change in surgical technique from an anterolateral approach to the DAA.

One of the main reasons for adopting the DAA technique is the reduced dislocation rate. This study reports a dislocation rate of 0,9%, which is similar with other reports in the DAA-THA literature (12,36,29,35,22,25,31,16,17,23,3,28,5). Furthermore, the concerning finding of an unacceptable high number of intra-operative femoral fractures (up to 27%) in the literature regarding DAA on a positioning table was not reproduced in our study (1,8,9,14,21). The benefits of supine positioning on a regular OR table has been reported earlier by Lovell, who argues that stability and leg length is much easier to assess. Moreover, a circulating nurse is not required to reposition the leg (19).

In addition, no outliers in cup positioning were detected during the first 50 cases. So in this series, cup positioning using DAA in supine position has shown little susceptibility to the adverse effects of the learning curve (38).

Another concern with the use of the DAA, is the risk of injury to the LFCN. Varying percentages ranging from zero to 81% are reported in literature (3,6,9,28). We believe that the relatively low percentage of LFCN injury in this study is due to the surgical technique. A lateralised incision, centred over the muscle belly of the tensor fascia lata, will mitigate the risk of LFCN injury. Also, in our series, a lesser amount of wound problems compared with the high number of 4,6% (by Jewett and Collis) was observed. Again these studies were done using an orthopaedic table (14). The anterior skin is noticeable thin and continuous traction could cause blood flow restriction and increased shear forces, which could result in wound problems.

Also, the data provides a trend towards non-inferiority compared with DAA technique using traction devices or orthopaedic table. In addition, a Bayesian meta-analysis from De Geest et al. in 2015 could not find a significant difference in risk incidence of intra-operative femoral fractures, however the risk with the positioning table was higher compared to a regular OR table (0,2% vs 0,7%)

Table 3. — overview of studies reporting complications of DA-THA in supine position without traction devices. x : not reported

	Dislocation (rate)	SSI (superficial/deep)	Intra-op GT or calcar fracture	Intra-operative femoral fracture / perforation	Femoral or sciatic nerve lesion
Keggi 1993 (n=1000) 787 primary THR 313 revisions; all percentages based on primary THR group	17 (2,5%) in primary THR 7 obese pt 5 complex reconstructions 3 poor mental status	1 deep (0,2%)	10 calcar (1,5%) 5 significant GT (0,7%)	5 proximal femoral fractures (3 complex DDH cases, 1 femoral malunion case)	5 partial nerve palsies (0,7%) ?
Kennon 2003 (n=2132) (cemented + uncemented) 283 complex cases Only complications during first 6 months postop	28 (1,3%), 1 open reduction	7 infections (not specified)	29 GT (4 fixations) 3 LT (1 fixation) 38 Calcar (1 cerclage)	21 femoral shaft 3 acetabular	4 transient Sciatic nerve palsies, no residual injury
Nakata 2008 (n=195) Consecutive series	0	1 superficial 0 deep	1 calcar fracture, 1 significant GT fracture	0	0
Lovell 2008. Technique description with some complications reported	x	x	x	x	x
Berend 2009 (n=258) series	0	2 superficial (debridement & irrigation) 0 deep	x	2 proximal femoral perforations 1 pelvic fracture requiring revision acetabular component	0
Seng 2009 n=182 (partially same population as Berend 2009?)	x	2 superficial (debridement & irrigation) 0 deep	x	2 proximal femoral perforations 1 pelvic fracture requiring revision acetabular component	x
Restrepo 2010 (n=50) RCT	0	0	0	0	0
Bergin 2011 n=29 (DAA) prospective	0	0	0	0	0
Hallert 2012 n=200	6 (1 stem revision, 1 cup + stem revision)	1 superficial 1 deep (DAIR)	x	3 non-specified	1 peroneal nerve transient 1 femoral nerve transient
Unger 2014 n=180 NOF fractures Bipolar hemi-arthroplasty	1 (0,6%) dysplasia case	3 superficial 1 deep (2-stage revision)	0	0	1 femoral nerve (incorrect sharp retractor placement)
Frye 2014 n=421	x	x	x	x	x
Rodriguez 2014 n=60	0	0	1 undisplaced GT frx	0	0
Tsukada 2015 n=139	0	0	2 (1,4%)	2 (1,4%)	1 (0,7%) (femoral nerve)
Mirza 2015 n=1035 Mean follow-up = 40 m (12-60)	4 (0,4%)	1 deep (0,1%)	x	2 perforations	x
Berend 2016 n=2869 Only looked for periprosthetic fractures	x	x	x	x	x
Parvizi 2016 n=44 RCT (DAA vs Lateral)	1	1 persistent drainage (DAIR)	x	1	x
Sang 2016 n=124	0	x	1 GT fracture	0	0

Table 3. — overview of studies reporting complications of DA-THA in supine position without traction devices. x : not reported

LFCN (neuropraxia / permanent)	Hematoma	Other: Ceramic liner / head fracture, clicking, squeaking ...	Total intra-op complications	Total postoperative complications (SSI, dislocation, other)	Medical complications: DVT/PE, cardiac ...	Remarks from author
x	13 (1,9%)	x	20 significant I.O. fractures (3%)	x	5 DVT/PE (VTE) (0,7%) very low percentage!	x
5	31	X	87 intra-op fractures (overlap with groups GT/ LT/ Calcar)	x	6 DVT 11 PE 12 non-fatal MI or CVA 1 fatal MI	30 lost to follow-up before 6 months
1 LFCN hyperesthesia	x	0 subsidence 0 cup migration	2	0 postop femoral fractures	1 DVT	More cups in safe zone compared to PA
5% temporary < 1% permanent	x	x	x	x	x	x
2 temporary (resolved)	x	1 cup dislodgement (revised intra-operative)	4	4 peri-prosthetic fractures (all requiring stem revision)	0 DVT's	6 reoperations Better hip scores at 6 weeks
2 temporary (resolved)	x	1 cup dislodgement (revised intra-operative)	Overall 5,4% (10/182)	2 peri-prosthetic fractures (all requiring stem revision)	No DVT/PE	x
2%	0	0	0	1 periprosthetic fracture requiring revision 1 cup loosening requiring revision	0	x
0	1	0	0	0	0	Better implant position compared to PA group
1 transient	x	x	x	x 2 revisions for instability 1 DAIR	3 DVT	no learning curve, excellent results, no recurrent dislocations
0	12% prolonged wound healing	x	x	3 seroma requiring reoperation	22,8% transfusion rate	modified DAA for hemiarthroplasty
x	x	0,83 mean TFL damage score	x	x	x	more TFL damage in males and high BMI
40% transient numbness, 0% persistent	x	1 Brooker grade 2	x	4 groin pain	x	x
x	x	1 (liner fracture) 3 clicking 2 squeaking	x	x	x	x
no exact data	x	x	Overall complication rate 1,7%	9 (0,9%) early postop periprosthetic fractures, all revised	Transfusion rate 5%	x
x	x	x	26 (0,9%) early periprosthetic femoral fractures (23 revisions)	x	x	x
x	x	x	x	x	x	Not mentioned to which group complications belong?
1	1	x	3	x	x	x

(8). In Table 3, all papers of DAA-THA in supine position on a regular OR table are summarised, the complication rates are comparable with our results. Interesting to note is that even in the studies on a regular OR table, many authors describe either the use of a table-mounted femoral elevator (Omni-Tract Surgical, St. Paul, MN) or a considerable amount of femoral hyperextension (3,32).

Our study has strengths and limitations. This study adds a large series of evidence to the data on DAA-THA on a regular OR table in supine position. To our knowledge this study is the first to report a series where femoral hyperextension is omitted. The primary weakness of this study is the retrospective design. Inherent bias applies to all retrospective studies and therefore also to our data analysis. In addition, our study does not include a comparison group. We recognise this, but the aim of the study was to record intra-operative complications and reoperations. The percentages of the complications and reoperations are calculated on 356 hips, with 16 patients who could not attend a clinical review nor a telephone survey during the study period. As a result, we could have missed some late postoperative complications or reoperations that have been treated elsewhere. Therefore the complication rate might be slightly underestimated. In addition we can acknowledge a short term follow-up of more than 30 months which is relatively long in DAA literature.

To conclude, this consecutive series DAA-THA in supine position on a regular OR table without femoral hyperextension has demonstrated a safe technique with a low intra-operative and postoperative complication ratio, this in contrast to some of the previous publications using extension devices. A meta-analysis comparing complication data of DAA-THA with or without traction devices is warranted.

## REFERENCES

1. 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.
2. Barton C, Kim PR. Complications of the direct anterior approach for total hip arthroplasty. *Orthop Clin North Am.* 2009 ; 40 : 371-375.
3. Berend KR, Lombardi AV Jr, Seng BE, Adams JB. Enhanced early outcomes with the anterior supine intermuscular approach in primary total hip arthroplasty. *J Bone Joint Surg Am.* 2009 ; 91 : 107-120.
4. Berend KR, Mirza AJ, Morris MJ, Lombardi AV Jr. Risk of Periprosthetic Fractures With Direct Anterior Primary Total Hip Arthroplasty. *J Arthroplasty* 2016 ; 31 : 2295-2298.
5. 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 : 1392-1398.
6. Bhandari M, Matta JM, Dodgin G, et al. Outcomes following the single-incision anterior approach to total hip arthroplasty : a multicenter observational study. *Orthop Clin North Am.* 2009 ; 40 : 329-342.
7. Chen M, Luo Z, Ji X, Cheng P, Tang G, Shang X. Direct Anterior Approach for Total Hip Arthroplasty in the Lateral Decubitus Position : Our Experiences and Early Results. *J Arthroplasty* 2016 ; 32 : 131-138.
8. De Geest T, Fennema P, Lenaerts G, De Loore G. Adverse effects associated with the direct anterior approach for total hip arthroplasty : a Bayesian meta-analysis. *Arch Orthop Trauma Surg.* 2015 ; 135 : 1183-1192.
9. De Geest T, Vansintjan P, De Loore G. Direct anterior total hip arthroplasty : complications and early outcome in a series of 300 cases. *Acta Orthop Belg.* 2013 ; 79 : 166-173.
10. Frye BM, Berend KR, Lombardi AV Jr, Morris MJ, Adams JB. Do sex and BMI predict or does stem design prevent muscle damage in anterior supine minimally invasive THA? *Clin Orthop Relat Res.* 2015 ; 473 : 632-638.
11. Ghijssels SG, Driesen R, Simon JP, Corten K. Distal Extension of the Direct Anterior Approach to the Hip : A Cadaveric Feasibility Study. *J Arthroplasty* 2017 ; 32 : 300-303.
12. 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.
13. Heuter C. Fünfte Abtheilung : Die Verletzung und Krankheiten des Hüftgelenks. In : Grundriss der Chirurgie. 2nd ed. Leipzig. FCW Vogel. 1883.
14. Jewett BA, Collis DK. High complication rate with anterior total hip arthroplasties on a fracture table. *Clin Orthop Relat Res.* 2011 ; 469 : 503-507.
15. Judet R, Judet J. Technique and results with the acrylic femoral head prosthesis. *J Bone Joint Surg Br.* 1952 ; 34 : 173-180.
16. Keggi KJ, Huo HH, Zatorski LE. Anterior Approach to Total Hip Replacement : Surgical Technique and Clinical Results of Our First One Thousand Cases Using Non-Cemented Prostheses. *Yale J Biol Med.* 1993 ; 66 : 243-256.

17. Kennon RE, Keggi JM, Wetmore RS, *et al.* Total hip arthroplasty through a minimally invasive anterior surgical approach. *J Bone Joint Surg Am.* 2003 ; 85 : 39-48.
18. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am.* 1978 ; 60 : 217-220.
19. Lovell TP. Single-incision direct anterior approach for total hip arthroplasty using a standard operating table. *J Arthroplasty.* 2008 ; 23 : 64-68.
20. Martin CT, Pugely AJ, Gao Y, Clark CR. A comparison of hospital length of stay and short-term morbidity between the anterior and the posterior approaches to total hip arthroplasty. *J Arthroplasty.* 2013 ; 28 : 849-854.
21. Matta JM, Shahrdar C, Ferguson T. Single-incision Anterior Approach for Total Hip Arthroplasty on an Orthopaedic Table. *Clin Orthop Relat Res.* 2005 ; 441 : 115-124.
22. Mirza AJ, Lombardi AV Jr, Morris MJ, Berend KR. A mini-anterior approach to the hip for total joint replacement : optimising results : improving hip joint replacement outcomes. *Bone Joint J.* 2014 ; 96 : 32-35.
23. 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 : 698-704.
24. Oinuma K, Eingartner C, Saito Y, Shiratsuchi H. Total hip arthroplasty by a minimally invasive, direct anterior approach. *Oper Orthop Traumatol.* 2007 ; 19 : 310-326.
25. Parvizi J, Restrepo C, Maltenfort MG. Total Hip Arthroplasty Performed Through Direct Anterior Approach Provides Superior Early Outcome : Results of a Randomized, Prospective Study. *Orthop Clin North Am.* 2016 ; 47 : 497-504.
26. Pogliacomi F, Paraskevopoulos A, Constantino C, Marengi 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.
27. Post ZD, Orozco F, Diaz-Ledezma C, Hozack WJ, Ong A. Direct anterior approach for total hip arthroplasty : indications, technique, and results. *J Am Acad Orthop Surg.* 2014 ; 22 : 595-603.
28. Restrepo C, Parvizi J, Pour AE, Hozack WJ. Prospective randomized study of two surgical approaches for total hip arthroplasty. *J Arthroplasty.* 2010 ; 25 : 671-679.
29. Rodriguez JA, Deshmukh AJ, Rathod PA, *et al.* Does the direct anterior approach in THA offer faster rehabilitation and comparable safety to the posterior approach? *Clin Orthop Relat Res.* 2014 ; 472 : 455-463.
30. Rudert M, Horas K, Hoberg M, *et al.* The Wuerzburg procedure : the tensor fasciae latae perforator is a reliable anatomical landmark to clearly identify the Hueter interval when using the minimally-invasive direct anterior approach to the hip joint. *BMC Musculoskelet Disord.* 2016 ; 17.
31. Sang W, Zhu L, Ma J, Lu H, Wang C. The Influence of Body Mass Index and Hip Anatomy on Direct Anterior Approach of Total Hip Replacement. *Med Princ Pract.* 2016.
32. Seng BE, Berend KR, Ajluni AF, Lombardi AV Jr. Anterior-supine minimally invasive total hip arthroplasty : defining the learning curve. *Orthop Clin North Am.* 2009 ; 40 : 343-350.
33. Smith-Petersen MN. Approach to and exposure of the hip joint for mold arthroplasty. *J Bone Joint Surg Am.* 1949 ; 31 : 40-46.
34. Spaans AJ, van Hout J, Bolder SBT. High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. *Acta Orthop.* 2012 ; 83 : 342-346.
35. Tsukada S, Wakui M. Lower Dislocation Rate Following Total Hip Arthroplasty via Direct Anterior Approach than via Posterior Approach : Five-Year-Average Follow-Up Results. *Open Orthop J.* 2015 ; 9 : 157-162.
36. Unger AC, Dirksen B, Renken FG, *et al.* Treatment of Femoral Neck Fracture with a Minimal Invasive Surgical Approach for Hemiarthroplasty – Clinical and Radiological Results in 180 Geriatric Patients. *The Open Orthop J.* 2014 ; 8 : 225-231.
37. Wesseling M, Meyer C, Corten K, *et al.* Does surgical approach or prosthesis type affect hip joint loading one year after surgery? *Gait Posture* 2016 ; 44 : 74-82.
38. Woolson ST, Pouliot MA, Huddleston JI. Primary total hip arthroplasty using an anterior approach and a fracture table : short-term results from a community hospital. *J Arthroplasty.* 2009 ; 24 : 999-1005.