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Research Article

Randomized Study of Direct Anterior Approach versus Posterior Approach for Bipolar Hemiarthroplasty of the Hip

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Abstract

Background: The surgical approach of bipolar hemiarthroplasty of the hip is still controversial for clinicians today. This study focused on femoral stem insertion and positioning using two different approaches, the direct anterior approach (DAA) and the posterolateral (PA) approach, and evaluated radiographic parameters.

Methods: Twenty-nine patients were enrolled in a prospective, non-blinded study and were randomly assigned to receive surgery via either approach; 13 cases, the DAA group and 16 cases, the PA group, respectively. The groups were not significantly different with respect to age, gender, body mass index, and time from injury to operation. All surgery was performed under the direction of one surgeon and the femoral component was limited to the Taperloc (Biomet, Warsaw, IN) femoral stem. The primary outcome of this study was to calculate the canal fill ratio in the proximal metaphyseal area, which is considered to be the load center of this stem. As secondary objectives, we evaluated prosthetic anteversion, canal fill ratio in the other areas, operative data, perioperative complications and modified Harris Hip score at discharge.

Results: The DAA group had a better canal fill ratio in the proximal metaphyseal area (66% versus 61%) from the AP (anterior-posterior) view only. However, the average of the canal fill ratio from the AP and lateral views was not different between the DAA group and the PA group (65% vs 64%). Prosthetic anteversion was 18.1 degrees and 26.2 degrees in the DAA group and the PA group, respectively (P = 0.09). There was no significant difference in modified Harris Hip score between the DAA group (47.3 ± 15.85 points) and the PA group (50.5 ± 13.14 points ; P = 0.558.)

Conclusion: The result of the study suggested initial fixations of stems from cross-sectional view were not different between the DAA group and the PA group regardless of prosthetic anteversion.

Keywords: Direct Anterior Approach; Posterior Approach; Bipolar Hemiarthroplasty of the hip; Learning Curve; Anteversion

Abbreviations

BHA: Bipolar Hemiarthroplasty;

CT: Computed Tomography;

DAA: Direct Anterior Approach;

PA: Posterolateral Approach;

THA: Total Hip Arthroplasty

Introduction

Femoral neck fractures have increased rapidly in line with the aging population in Japanese society. Bipolar hemiarthroplasty (BHA) is frequently used by many surgeons to treat femoral neck fractures, and many studies have subsequently reported good outcomes following the procedure [1-3].

Several surgical approaches have been investigated for hip surgery. Using the direct anterior approach (DAA), muscle detachment can be avoided [4-6] and several studies have reported satisfactory outcomes due to rapid recovery of hip joint function after total hip arthroplasty (THA) [7-9]. However, many surgeons still prefer the posterolateral approach (PA) after becoming accustomed to it and reaching a plateau in their learning curve [10].

Several reports about BHA indicate the earlier restoration of walking ability via the DAA than the PA [1,11], but there are few randomized studies comparing the accuracy of femoral stem insertion via both the DAA and PA. Therefore, we performed a prospective study, focusing on the positioning of the implant. Improving the fit and fill of cementless stems in the femoral canal is necessary for initial fixation and avoiding proximal bone resorption due to stress shielding [12-14]. The purpose of this study was to compare femoral stem positioning in the DAA group vs. the PA group. The primary outcome of this study was to calculate the canal fill ratio in the proximal metaphyseal area, which is considered to be the load center of this stem. As secondary objectives, we evaluated prosthetic anteversion, canal fill ratio in the other areas, operative data, perioperative complications and modified Harris Hip score at discharge.

Materials and Methods

We chose 48 patients diagnosed with a femoral neck fracture (Garden type III-IV [15]) from April 2012 to April 2013. 19 Patients were excluded because of obesity (5 patients, body mass index ≥30 kg/m2), muscularity (1 patient's), osteoporosis (7 patients, Singh grade I-II [16]), narrow or wide femoral canal (5 patients, Dorr type A or C) and tumor-bearing (1 patient). Twenty-nine patients were enrolled in the prospective, non-blinded study and were randomly assigned by the envelope method to undergo BHA either via the DAA or the PA. Institutional ethical committee approval was obtained and informed consent was provided by all patients. All preoperative data were summarized in Table 1.

Table 1. Preoperative clinical data

	DAA (*N* =13)	PA (*N* = 16)	*P*-value
Age (years)	81.46 ± 6.83	78.63 ± 7.00	0.283
Gender (M/F)	4/9	5/11	0.647
BMI (kg/m^2)	20.87 ± 2.66	20.24 ± 3.85	0.723
Time from injury to operation (days)	3.92 ± 3.52	4.93 ± 2.83	0.398
MMSE(max = 30)	14.92 ± 13.02	15.56 ± 10.81	0.886

DAA, direct anterior approach; F, female; M, male; max, maximum;

MMSE, Mini-Mental State Examination; PA, posterolateral approach.

Data are mean values ± standard deviation.

Methods

All surgery was performed under the direction of one experienced surgeon who had performed over 300 BHA operations and was accustomed to both surgical approaches. We limited the femoral component to the Taperloc TM femoral stem (Biomet, Warsaw, IN). This stem is composed of a titanium alloy with a circumferential plasma-spray coating on its proximal third and a porous plasma-spray coating (PPS®) that allows for initial scratch-fit stability and bone fixation [17,18].

Operative techniques

Both approaches were performed using spinal anesthesia.

DAA cases were performed with a slight modification of the technique described by Lovell [6], and Moskal et al. [19]. The patient was positioned supine on the operating table. To assist femoral exposure, the operative leg was externally rotated and the hip joint was extended 25-30° by bringing the foot to the floor. We used a longitudinal incision that began 2-3 cm posterior and1-2 cm distal from the anterior superior iliac spine and extended distally to the tensor fascia lata muscle belly. The underlying fascia between the tensor muscle and the sartorius was dissected and bluntly swept. The anterior articular capsule was exposed, incised, and resected as much as possible to expose the femoral head. For stem insertion, the surgical table was extended so that the hip joint could be extended to

15°. The superior and posterior portions of the articular capsule were partly incised so that the greater trochanter could be elevated with a retractor. The femoral canal was prepared with reamers and rasps. After testing the trial components, the femoral component and modular head were inserted. We performed this approach without using fluoroscopy, and the skin incision was approximately 8-10 cm.

The PA was modified to optimize it for Japanese patients [20]. Patients were placed in the lateral decubitus position. The line between the top of the greater trochanter and Gerdy's tubercle was drawn and we pointed 14 cm distal to the top of the greater trochanter on this line (point A). We added the perpendicular line that was 4 cm distal to the top of the greater trochanter and pointed 4 cm posterior to the initial point (point B). We drew a line between point A and point B and made an incision on this line around point B. The gluteus maximus was separated along the muscle without cutting any fibers. Then the gluteus medius was retracted in an anterior direction and short rotators were exposed. With the leg internally rotated, the piriformis tendon, the superior gemellus, and the inferior gemellus were released subperiosteally from the greater trochanter and the capsule was then incised. The femoral head was dislocated posteriorly and the femoral neck was cut using a bone saw. The extirpated head was measured and the trial prosthetic head was tested. The leg was internally rotated and the proximal femur was elevated. The femoral canal was prepared with reamers and rasps. After the trial components were tested, the femoral component and modular head were inserted. The capsule and short rotators were repaired. We performed this approach without using fluoroscopy, and the skin incision was about 8-10 cm.

Postoperative Care

All patients received standardized postoperative care. Mechanical foot pumps and pharmacological antithrombotic prophylaxis were used. Patients received antibiotics for the postoperative period. Physical therapy began the day after surgery. Most of the patients were transferred to a rehabilitation facility.

Radiographic analysis

Computed tomography (CT) imaging was performed no later than a week after the operation. Horizontal 2-mm thick slices were scanned starting superior to the pelvis and continuing distal to the knee, and three-dimensional images were reconstructed.

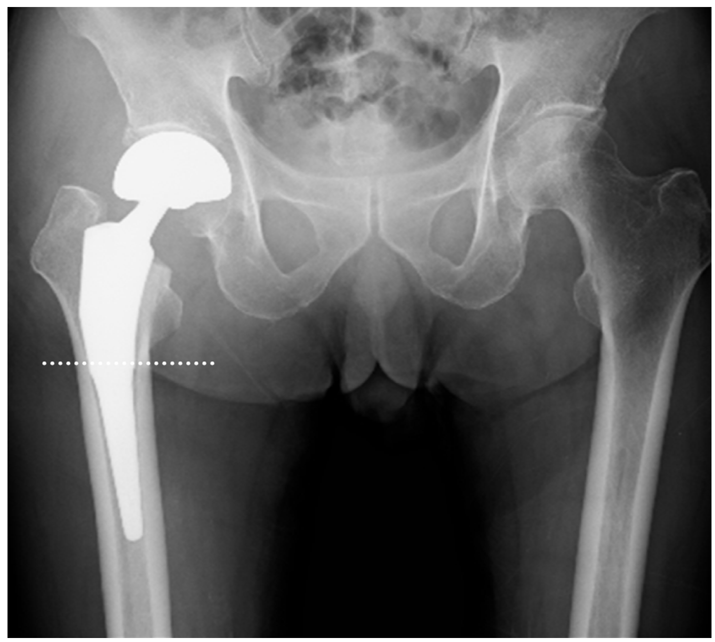
Prosthetic anteversion was assessed as the angle between the line from the center of the prosthetic femoral head to the femoral neck and the posterior condylar line [21].

Canal fill ratio was calculated according to the method of Laine et al. [12]. It was measured in two steps, by measuring stem and canal widths from the anterior-posterior (AP) view and the medial-lateral (ML) view, and then calculating the average fill for AP and ML views (average of AP and ML views) as shown in Figure 1.

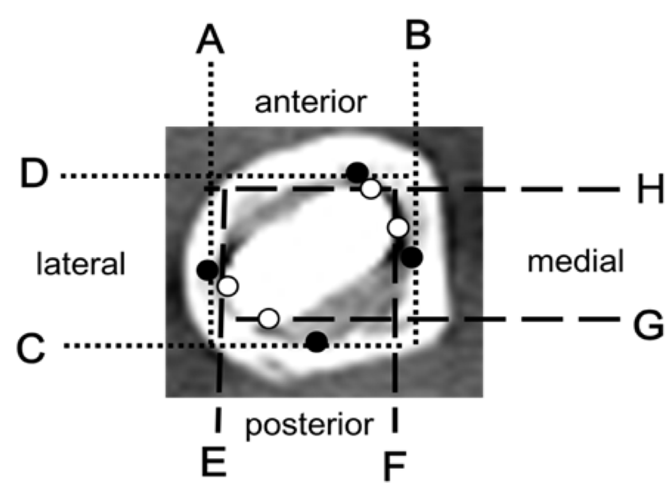
The canal fill ratio according to AP view = EF/AB

The canal fill ratio according to ML view = HG/CD

AB and CD refer to femoral canal width, and EF and HG refer to stem width in the anteroposterior and lateral views.



Femoral canal fill at a level 5 mm below the apex of the lesser trochanter.(Fig 1A)



Radiographic image with dashed line representing CT location. (Fig 1B)

Canal fill ratio was calculated at a 5-mm slice interval from 20 mm above to 20 mm below (i.e., the proximal and distal metaphysis, respectively) the apex of the lesser trochanter, which is considered to be the load center of this stem. Similarly, the canal fill ratio of the diaphysis was calculated at 10-mm intervals 50 mm below the mid-point of the lesser trochanter and 10 mm proximal to the stem tip.

Radiographic analysis from a reconstructed CT image. AB and CD refer to femoral canal width. EF and HG refer to stem width. Filled circles represent inner diame.

We calculated the stem alignment using the method of Hirata et al. [22]. Coronal stem alignment was calculated from the angle between the stem axis and the proximal femoral axis in the coronal plane. When the stem axis inclined >2° in a varus or valgus angle compared to the proximal femoral axis, coronal stem alignment was said to be in varus or valgus tilt.

Statistical analysis

All analyses of the clinical, biological, and radio-graphical data were performed by a single observer (H.A). Statistical analysis was performed using SPSS ver21 (IBM€). Continuous variables between the two groups were compared using a Student's t-test for paired-samples. For nominal variables, we used the Chi-square ($\chi 2$) test. A P value of <0.05 was considered to be significant. Power analysis indicated that adequate number for this study was approximately 15-20 cases when we postulated that the valuable differences between both approaches were 5.0% for canal fill ratio and 10.0° for prosthetic anteversion and the standard deviation of canal fill ratio and prosthetic anteroversion were approximately 5.0% and 10.0 °, respectively (power=0.8).

Moreover, for evaluation of the learning effect on operative outcomes, we divided both DAA and PA groups into halves. For each subgroup, we defined the first half as early phase and the second half as late phase and clinical date were compared.

Results

All operative data are summarized in Table 2. There was no significant difference in femoral head size, stem size, and total blood loss. Duration of the operation was significantly longer in the DAA group (85.61 min vs. 61.75 min in the PA group).

In the DAA group, it was determined radio graphically that 10 (77%) of the 13 stems were in the neutral position, one stem was in the varus position, and two stems were in the valgus position. In the PA group, 13 (81%) of the 16 stems were in the neutral position and three stems were in the valgus position. Prosthetic anteversion was 18.1 ± 11.1 ° and 26.2 ± 10.7 ° in the DAA group and the PA group, respectively (P = 0.09). Table 3 shows an analysis of canal fill ratios. The PA group had a better canal fill ratio in the diaphyseal area (42% vs. 33%), but there was no difference in the proximal metaphyseal area, where it is considered to be the load center for this stem.

In regards of learning effect, total blood loss was numerically less in the late phase of the DAA group (45 ± 35 ml vs. 241 ± 135 ml in the early phase; P = 0.09). However, no improvement was observed in canal fill ratio in the late phase of the DAA group (the average of the AP and ML views at the proximal metaphysis was 64 ± 2% vs. 67 ± 6% in the early phase). In the PA group, the late phase subgroup was not associated with an improvement of any values measured (the average of the AP and ML views at the proximal metaphysis was 64 ± 7% vs. 63 ± 6% in the early phase).

Table 4 showed side effects of the surgical procedures in the perioperative periods (until discharge). There were no dislocations or postoperative infections (including superficial or deep infections at the surgical site). Two cases of periprosthetic femoral fractures (classified as Vancouver type A) occurred during surgery in the DAA group. Cable fixation around the greater trochanter was required in one of these cases. No dislocations occurred in the postoperative period.

Most of the patients were discharged to a rehabilitation facility. Early clinical results were assessed using the modified Harris Hip Score [23] at discharge. There was no significant difference between the DAA group (47.3 ± 15.85 points) and the PA group (50.5 ± 13.14 points; P = 0.558.)

Table 2. Operative data

	DAA (*N* = 13)	PA (*N* = 16)	*P*-value
Component head size	43.7 ± 13.6	45.1 ± 2.4	0.682
Stem size	10.6 ± 1.8	10.8 ± 2.3	0.739
leg length discrepancy (mm)	-1.0 ± 8.3	3.0 ± 5.2	0.133
Duration of operation (min)	85.6 ± 14.5	61.8 ± 9.5	<0.001**
Total blood loss (ml)	198.3 ± 146.2	146.7 ± 133.1	0.409

DAA, direct anterior approach; PA, posterolateral approach.

** P value <0.05 was considered to be significant.

Data are mean values ± standard deviations.

Table 3. Femoral canal fill

	Canal Fill (%)								
	AP view			ML views			Average of AP and ML views		
Region	DAA (*N* = 13)	PA (*N* = 16)	*P*-value	DAA (*N* = 13)	PA (*N* = 16)	*P*-value	DAA (*N* = 13)	PA (*N* = 16)	*P*-value
Proximal metaphysis	66 ± 5	61 ± 6	0.036*	64 ± 9	68 ± 6	0.285	65 ± 5	64 ± 4	0.655
Distal metaphysis	73 ± 8	70 ± 6	0.311	65 ± 8	72 ± 9	0.151	70 ± 5	71 ± 5	0.548
Diaphysis	69 ± 13	74 ± 10	0.279	46 ± 9	55 ± 8	0.033*	58 ± 9	65 ± 7	0.064

AP, anterior-posterior; DAA, direct anterior approach; ML, medial-lateral; PA, posterolateral approach.

** P value <0.05 was considered to be significant.

Data are mean values ± standard deviations.

Note: The stem fill ratio was calculated at 5-mm slice intervals from 20 mm above (proximal metaphysis) to 20 below (distal metaphysis) the mid-point of the lesser trochanter. The canal fill ratio of the diaphysis was calculated at 10-mm intervals 50 mm below the midpoint of the lesser trochanter and 10 mm proximal to the stem tip.

Table 4. Perioperative complications.

Complications, n (%)	DAA (*N* = 13)	PA (*N* = 16)	*P*-value
Periprosthetic femoral fracture	2 (15)	0 (0)	0.104
DVT	3 (23)	2 (13)	0.316
Infection	0 (0)	0 (0)	NA
Dislocation	0 (0)	0 (0)	NA
Peroneal nerve palsy	1 (8)	1 (6)	0.879

DAA, direct anterior approach; DVT, deep vein thrombosis; n, number of patients; N, total number of patients in group; NA, not applicable; PA, posterolateral approach.

Note: Statistical differences between the methods were calculated using the χ^2 test.

Discussion

We performed a prospective randomized study. This study showed that initial fixations of stems from cross-sectional view were not different between the DAA group and the PA group regardless of prosthetic anteversion.

The DAA is considered to be a useful approach. Siguer et al. [24] reported a <1% dislocation outcome as an advantage of the DAA. Nakata et al. [9] showed a more rapid recovery of hip function was possible using the DAA vs. the mini-posterior approach; this is because the external short rotators, which play an important role in hip function and stabilization, were preserved. The time needed until a single-leg stance or walking with a single cane was possible, was more rapid in the DAA group than in the mini-posterior group of patients. It should be noted that the PA is accepted by many surgeons once they become accustomed to this surgical procedure and can perform it safely. However, when using this approach it is necessary to detach the external short rotators and it can increase the risk for damage to the sciatic nerve [25].

Several studies have reported inferior results for the DAA to the other approaches [26]. They specifically pointed out its association with a longer operation time and more blood loss. Because there is a learning curve associated with the DAA [26], it is difficult to compare it to the PA. Although our surgical team had gained experience by performing >20 operations before this study began, we conceded that the effect of the learning curve was undeniable. However, in regards of the canal fill ratio, any learning effects were not observed in time course.

Fit and fill parameters of cementless stems are important factors in improving component stability and clinical results [28]. Martell et al. [28] reported that aseptic loosening was related to lower canal fill ratio in both the metaphyseal and the diaphyseal regions, and stem subsidence was inhibited by a tight metaphyseal fill. Insufficient canal filling may lead to thigh pain, prosthetic loosening, or implant fracture [29]. To evaluate component stability and clinical results, we calculated stem parameters using CT. Based on the cross-sectional data acquired using artifact reduction techniques in CT, we endeavored to make the canal fill ratio more reliable. We limited the femoral stem to the proximal fixation type. The canal fit of the proximal femur relates to the initial fixation of the stem [30]; thus, we regarded the canal fill ratio of its point as important. In this study, the canal fill of the proximal metaphyseal area from the AP view was less in the PA group (61% versus 65%). However the average of the canal fill ratio in the proximal metaphyseal area did not differ in either group.

The poor canal fill ratio in the PA group from the AP view was probably due to steeper prosthetic anteversions. This result implied the anxieties of surgeons about dislocation. The PA detaches short rotator muscles and posterior articular capsule and increases the possibility of posterior dislocation. Steeper prosthetic anteversion prevents the mechanical stress to the posterior wall of the hip joint [31]. Our result of this study indicated this mechanism.

The strengths of this study include the standardized protocol in relation to the stem component and the surgical team. We strictly excluded the patients with barriers that influenced surgical out comes or insertion of the stem. This facilitated accurate radiographic assessments so that we could more reliably analyze the data. Moreover, the advantage of this study was that we calculated canal fill ratio using cross-sectional CT images. This method reduced errors in radiological estimations.

We acknowledged several limitations of this study. First, the sample size may have been inadequate. Takeshi [31] stated the lower femoral anteversion (<10°) limited the range of motion of flexion and internal rotation due to bone impingement. For every 10° augmentation of anteversion, the range of motion of flexion and internal rotation was increased by 6.3°, 11.1°, respectively. So, if 10 ° inclination of anteversion was considered to be clinically relevant and standard deviation of anteversion was postulated 10°, the power of our study can be approximately 0.80. Second, we cannot ignore the effect of the learning curve, especially in the DAA group. Third, we did not focus on the interaction between positioning of the implant and the clinical outcome. We know the patient reported outcomes are very important for evaluating post-operative parameters, but most of the patients in this study had such severe dementia tha precise evaluations of the outcome were difficult to analyze. Further prospective studies are necessary to clinically evaluate implant survivorship, thigh pain, long-term complications, and other factors.

In conclusion, the canal fill ratio in the proximal metaphyseal area was different according to the ratio calculated from the different views. But, the average of the canal fill ratio in this era did not differ between the DAA group and the PA group. Thus, the initial fixation of the stem was considered to be the same in this study.

Conflicts-of-interest

The authors have no potential conflicts-of-interest to disclose.

References

1. Baba T, Shitoto K, Kaneko K. Bipolar hemiarthroplasty for femoral neck fracture using the direct anterior approach. World J Orthop. 2013, 4(2): 85–89.

2. Laflamme GY, Rouleau DM, Leduc S, Roy L, Beaumont E. The Timed Up and Go test is an early predictor of functional outcome after hemiarthroplasty for femoral neck fracture. J Bone Joint Surg Am. 2012, 94(13): 1175–9.

3. Taylor F, Wright M, Zhu M. Hemiarthroplasty of the hip with and without cement: a randomized clinical trial. J Bone Joint Surg Am. 2012, 94(7): 577–83.

4. Ueo T, Kobayashi T, Ishibe T. Total hip arthroplasty using direct anterior approach. J Joint Surg. 2007, 26: 93-100.

5. Kennon R, Keggi J, Zatorski LE, Keggi KJ. Anterior approach for total hip arthroplasty: Beyond the minimally invasive technique. J Bone Joint Surg Am. 2004, 86–A Suppl 2: 91-97.

6. Lovell TP. Single-incision direct anterior approach for total hip arthroplasty using a standard operating table. J Arthroplasty. 2008, (Suppl)23: 64–8.

7. Barrett WP, Turner SE, Leopold JP. Prospective randomized study of direct anterior vs postero-lateral approach for total hip arthroplasty. J Arthroplasty. 2013, 28(9): 1634–1638.

8. Rodriguez JA, Deshmukh AJ, Parthiv A, Greiz ML, Deshmane PP 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(2): 455–63.

9. 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.

10. Swanson TV. Posterior single-incision approach to minimally invasive total hip arthroplasty. Int Orthop. 2007, (Suppl): S1–5.

11. Nakata K, Tsuda K, Nishikawa M. Efficacy of direct anteri-

or approach in minimally invasive total hip arthroplasty: Comparative clinical study with posterior approach combined enhanced repair of superoposterior soft-tissue. J Musculoskeletal System. 2006, 391–398.

12. Laine H-J. Anatomy of the proximal femoral medullary canal and fit characteristics of cementless endoprosthetic stems. (Academic Dissertation). Retrieved from Acta Electronica Universitatis Tamperensis 2001.

13. Engh CA, Glassman AH, Suthers KE. The case for porous-coated hip implants. Clin Orthop. 1990, 261: 63–81.

14. Engh Jr CA, Culpepper WJ II, Engh CA. Long-term results of use of the anatomic medullary locking prosthesis in total hip arthroplasty. J Bone Joint Sur Am. 1997, 79(2): 177–84.

15. Garden RS. Stability and union in subcapital fractures of the femur. J Bone Joint Surg Br. 1964, 46: 630-47.

16. Singh M, Riggs BL, Beabout JW, Jowsey J. Femoral trabecular pattern index for evaluation of spinal osteoporosis. A detailed methodologic description. Mayo Clin Proc. 1973, 48(3): 184–9.

17. Parvizi J, Keisu KS, Hozak WJ, Sharkey PF, Rothman RH. Primary total hip arthroplasty with an uncemented femoral component: a long-term study of the Taperlock stem. J Arthroplasty. 2004, 19(2): 151–6.

18. Mc Laughlin JR, Lee KR. Total hip arthroplasty in young patients. 8- to 13-year results using an uncemented stem. Clin Orthop Relat Res. 2003, 373: 153–63.

19. Moskal JT, Capps SG, Scanelli JA. Anterior muscle sparing approach for total hip arthroplasty. World J Orthop. 2013, 4(1): 12–8.

20. Hirotaka I, Takanobu O, Toshiyuki K, Takayuki H. Postero-lateral minimally invasive surgery for cementless hip arthroplasty optimized for Japanese patients. Japanese J Joint Dis. 2008, 4: 450–7.

21. Pierchon F, Pasquir G, Cotton A, Fontaine C, Clarisse J et al. Causes of dislocation of total hip arthroplasty. CT study of component alignment. J Bone Joint Surg Br. 1994, 76(1): 45-8.

22. Hirata M, Nakashima Y, Ohishi M, Hamai S, Hara D et al. Surgeon error in performing intraoperative estimation of stem anteversion in cementless total hip arthroplasty. J Arthroplasty. 2013, 28(9): 1648–53.

23. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969, 51(4): 737–55.

24. Siguier T, Siguier M, Brumpt B. Mini-incision anterior approach does not increase dislocation rate: a study of 1037 total hip replacements. Clin Orthop Relat Res. 2004, 426: 164–73.

25. Dietze S, Perka C, Baecker H. Blood vessel and nerve damage in total hip arthroplasty. Orthopade. 2014, 43(1): 64–9.

26. D'Arrigo C, Speranza A, Monaco E, Carcangiu A, Ferretti A. Learning curve in tissue sparing total hip replacement: comparison between different approaches. J Orthop Traumatol. 2009, 10(1): 47–54.

27. 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): 342–6.

28. Martell JM, Pierson RH 3rd, Jacobs JJ, Rosenberg AG, Maley M et al. Primary total hip reconstruction with a titanium fiber-coated prosthesis inserted without cement. J Bone Joint Surg Am. 1993, 75(4): 554–71.

29. Kim YH, Kim VE. Uncemented porous-coated anatomic total hip replacement. Results at six years in a consecutive series. J Bone Joint Surg Br. 1993, 75(1): 6–13.

30. Parvizi J, Keisu KS, Hozack WJ, Sharkey PF, Rothman RH. Primary total hip arthroplasty with an uncemented femoral component: a long-term study of the Taperloc stem. J Arthroplasty. 2004, 19(2): 151–6.

31. Takeshi S, Yuji Y, Takuma Y, Soutarou Im, Susumu H et al. Low femoral antetorsion as a risk factor for bony impingement after bipolar hemiarthroplasty. J Orthop Surg Res. 2015, 10: 105.