

Comparison of Minimally Invasive Total Hip Arthroplasty versus Conventional Hemiarthroplasty for Displaced Femoral Neck Fractures in Active Elderly Patients

Kyung-Soon Park, Chang-Seon Oh and Taek-Rim Yoon*

Center for Joint Disease, Chonnam National University Hwasun Hospital, Hwasun, Korea

Fractures of the femoral neck in elderly patients can be treated by internal fixation, hemiarthroplasty, or total hip arthroplasty (THA), and the treatment modality used should be determined on the basis of considerations of the degree of fracture displacement, age, functional demands, and the risk factors for surgery and anesthesia. We studied 85 active elderly patients who underwent minimally invasive two-incision THA or conventional bipolar hemiarthroplasty (BHA) within 2 weeks of injury for the treatment of acute displaced femoral neck fractures. Patients were followed up for a minimum of 24 months. The average operation times were 70 minutes in the THA group and 46 minutes in the BHA group ($p=0.002$), and average blood losses during the perioperative period were 921 cc and 892 cc, respectively ($p=0.562$). In the THA group, the average postoperative Harris hip score was 88.3 and the average Western Ontario and McMaster University score was 28.8, whereas in the BHA group the corresponding scores were 80.4 ($p=0.006$) and 32.5 ($p=0.012$), respectively. There were 2 cases of hip dislocation in the THA group, and 2 cases in the BHA group underwent conversion to THA. Our short-term follow-up results were better for minimally invasive two-incision THA than for conventional BHA for the treatment of acute displaced femoral neck fractures in active elderly patients.

Key Words: Femoral neck fractures; Arthroplasty; Hemiarthroplasty

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article History:

received 1 July, 2013

revised 13 July, 2013

accepted 14 July, 2013

Corresponding Author:

Taek-Rim Yoon

Center for Joint Disease, Chonnam
National University Hwasun Hospital,
160 Ilsim-ri, Hwasun-eup, Hwasun
519-809, Korea

TEL: +82-61-379-7676

FAX: +82-61-379-7681

E-mail: tryoon@chonnam.ac.kr

INTRODUCTION

The aging of the population has substantially increased the number of elderly patients. Most femoral neck fractures occur in the elderly population, because elderly persons are more likely to be osteoporotic and are more likely to sustain low-energy traumas such as falls. Approximately 1.3 million femoral neck fractures were reported worldwide in 1990, and this figure is expected to double by 2025 and to increase to about 4.5 million by 2050.¹ It is well known that fractures of the femoral neck in elderly patients can be treated by internal fixation, hemiarthroplasty (HA), or total hip arthroplasty (THA), and that the treatment modality used should be determined on the basis of considerations of degree of fracture displacement, age, functional demands, and the risk factors for surgery and anesthesia.

Hip joint arthroplasty has been performed in patient

groups such as those in whom maintaining reduction was difficult owing to severely displaced, pathologic fractures; those with severe osteoporosis; and elderly patients with systemic disease who need early ambulation. Of the different hip arthroplasties, bipolar hemiarthroplasty (BHA) has been widely performed owing to its relative simplicity and lower risk of hip dislocation.² However, long-term follow-up studies have revealed a high incidence of conversion to THA owing to groin pain and acetabular protrusion.³ Several comparative studies have been conducted on HA and THA for the treatment of femoral neck fractures in the elderly.^{4,5} Recently, Baker et al.⁴ and Blomfeldt et al.⁵ reported randomized controlled trials in which HA and THA were compared for the treatment of displaced femoral neck fractures in elderly patients. Their results indicated that THA has better functional results than does HA as soon as 1 year postoperatively without an increase in the complica-

tion rate.

The minimally invasive (MI) THA technique has been reported to reduce muscle injury, blood loss, and scarring at surgical sites and ultimately to shorten recovery time. In addition, it has been shown to increase patient satisfaction and to potentially shorten hospital stay.⁶ However, no comparative report has been issued on clinical results or analytical findings of HA and MI THA when used to treat femoral neck fractures in the elderly.

In this study, we retrospectively studied our arthroplasty results for elderly active patients with a displaced femoral neck fracture. We compared the results of MI two-incision THA and BHA with the conventional method to examine differences in perioperative morbidity and short-term clinical follow-up results.

MATERIALS AND METHODS

Between January 2002 and January 2006, 174 patients underwent hip arthroplasty for an acute displaced femoral neck fracture at our institute. A total of 91 patients underwent BHA, 63 underwent MI two-incision THA, and 20 underwent conventional THA. We retrospectively reviewed all patients and chose patients for this study by applying the following inclusion criteria: (1) age of over 60 years and unilateral injury; (2) surgery performed within 2 weeks of injury; (3) an American Society of Anesthesiologists score⁷ of less than 3, an activities of daily living (ADL)⁸ scale score of less than 2, and the ability to walk without limitation; and (4) a follow-up duration of greater than 2 years. Patients were divided into two groups, namely, the MI two-incision THA group and the conventional BHA group.

Eighty-five patients matched our inclusion criteria; there were 44 MI two-incision THA cases and 41 conventional BHA cases. In the MI two-incision THA group, there were 14 males and 30 females. Average age at injury was 71.6 years (range, 60-83 years), and causes of injury were a fall down in 8, a slip down in 34, and a traffic accident in 2. According to the Garden classification,⁹ there were 15 cases of type III and 29 cases of type IV. The mean follow-up period was 34.5 months (range, 25.1-49.8 months). The acetabular cup components used in the MI two-incision THA group were as follows: 39 cases of Secur-fit[®] (Howmedica Osteonics Stryker, Ireland), 3 cases of Trilogy[®] (Zimmer, USA), and 2 cases of Fitmore[®] (Centerpulse Orthopedics, Switzerland). The femoral components used were as follows: 23 Cone Prosthesis (Zimmer, Winterthur, Switzerland) and 21 M/L Taper (Zimmer, USA). Of the 41 patients in the BHA group, 11 were males and 30 were females. Average age at injury was 73.6 years (range, 60-85 years) and causes of injury were a fall down in 2, a slip down in 33, and a traffic accident in 4. According to the Garden classification,⁹ there were 19 type III and 22 type IV cases. Mean follow-up was 45.2 months (range, 27.7-72.3 months). All of the cases were treated with a cementless stem (Cone Prosthesis[®], Zimmer, Winterthur, Switzerland). The bipolar prostheses were all Osteo bipolar prostheses (Osteo AG, Switzer-

land). No significant baseline differences were evident between the two groups (Table 1).

All operations were performed by a single surgeon (T.R.Y.). MI two-incision THA was performed with the patient in the lateral position.¹⁰ An anterior skin incision was followed by intermuscular dissection between the gluteus medius and the tensor fascia lata. The joint capsule was exposed and incised, the femoral neck was osteomized and removed, and a cup was inserted after reaming the acetabulum. A posterior skin incision was then made along the fiber of the gluteus maximus, after intermuscular dissection between the piriformis and gluteus medius; the posterior joint capsule was incised; and a stem was inserted after broaching. The proximal femur was rotated anteriorly by traction and extension of the hip, and the trial head was inserted and reduced through an anterior opening site. Cementless acetabular and femoral components were used in all cases.

BHA was performed by using a conventional posterior incision. Short external rotators were dissected, and after femoral broaching, a stem and bipolar head were inserted. After implantation, short external rotators were repaired with nonabsorbable sutures by placing drill holes in the greater trochanter.

Clinical and radiological results were evaluated immediately after the operations, at 3 and 6 months postoperatively, and then every 6 months. Clinically, pain, ambulation, and range of motion according to Harris hip score (HHS)¹¹ and the Western Ontario and McMaster University (WOMAC) score¹² were evaluated to assess the postoperative function of the hip joint. Operation time, blood loss, and incision length were measured and postoperative ADL scores⁸ were compared as an evaluation of functional activities. The time of starting ambulation after surgery with walker or crutch was noted.

In terms of radiological evaluations, inclination and anteversion were calculated to evaluate acetabular cup alignment by using Widmer's method¹³ in the MI two-incision

TABLE 1. Demographics of the patients

Parameters	MI-THA	BHA
Number of hips	44	41
Gender (Male/Female)	14/30	11/30
Age (yrs)	71.6 (60-83)	73.6 (60-85)
Body mass index (kg/m ²)	21.5 (15.2-30.3)	22.0 (14.2-29.4)
Pre-injury ADL scale	0.13 (0-2)	0.15 (0-2)
Garden stage		
III	15	19
IV	29	22
Cause of injury		
Slip down	34	33
Fall down	8	4
Traffic accident	2	4

MI: minimal invasive, THA: total hip arthroplasty, BHA: bipolar hemiarthroplasty, ADL: activities of daily living.

THA group. Osteolysis of the acetabular cup was defined as cup migration of over 4 mm and of reactive line formation of thickness greater than 2 mm, as described by DeLee and Charnley's, during follow-up.¹⁴ Varus and valgus alignments of femoral components were evaluated by using Khalily and Lester's¹⁵ method. In addition, osteolysis of femoral components was assessed on anteroposterior and lateral radiographs by using Gruen's classification.¹⁶ A change of more than 3 degrees and a location change of more than 2 mm without bony ingrowth around the femoral component were considered as component subsidence. For conventional BHA, acetabular erosion was graded on last follow-up radiographs versus immediate postoperative radiographs.⁴

Limb length discrepancies were calculated by measuring the distance from the upper margin of the lesser trochanter to the line between both tear drops in anteroposterior radiographic views with the patients supine.

Statistical analysis was performed by using the independent t-test in the SPSS package (Base 13.0, SPSS Inc., Chicago, IL). *p* values of <0.05 were deemed significant.

RESULTS

For MI two-incision THAs, the average anterior incision length was 7.1 cm (range, 5.4-9.6 cm), the average posterior incision length was 4.5 cm (range, 3.5-7.5 cm), and the mean operation time from incision to skin closure was 70 minutes (range, 50-115 minutes). Mean blood loss was 920 cc (range, 450-1,450 cc). (Mean blood loss was defined as the total amount of fluid that collected in a suction bottle minus the amount of irrigation saline plus weight gains by gauzes and the total amount drained postoperatively.) Ambulation with weight-bearing crutches or a walker was started at a mean of 2.3 days (range, 1-7 days) postoperatively. Mean hospital stay was 15.1 days (range, 9-21 days).

For conventional BHA, the average skin incision length was 15.1 cm (range, 14-17 cm), and mean operation time from incision to skin closure was 46 minutes (range, 30-75 minutes). Mean perioperative blood loss was 891 cc (range, 420-1,410 cc). Ambulation with weight-bearing crutches or a walker was started at a mean of 5.3 days (range, 1-12 days) postoperatively, and mean hospital stay was 16.6 days (range, 9-25 days). Operation duration was significantly shorter in the BHA group, but time to assisted ambulation was shorter in the MI THA group. Group perioperative parameters were similar, except for duration of operation and ambulation time (Table 2).

For MI two-incision THA, the mean HHS score was 88.3 (range, 53-100) and the mean WOMAC score was 28.8 (range, 24-44) at the last follow-up visit. A total of 37 cases (84.1%) were clinically excellent or good (HHS > 80), and 2 cases with an aggravated spinal problem scored less than 70 points (HHS score of 61 and WOMAC score of 41, and HHS score of 53 and WOMAC score of 44, respectively). The mean ADL score was 0.34 (range, 0-4) at the last follow-up visit.

For conventional BHAs, mean HHS and WOMAC scores were 80.4 (range, 65-98) and 32.5 (range, 25-48), respectively, at the last follow-up visit. A total of 27 cases (65.9%) were clinically excellent or good (HHS > 80), and 6 cases scored < 70 points, including two cases of THA conversion. The mean ADL score was 0.66 (range, 0-5) at the last follow-up visit (Tables 3 and 4).

In the MI two-incision THA group, the average lateral opening angle of the acetabular components was 36.2° (range, 28.2-42.4°), and the average acetabular anteversion was 17.3° (range, 8.8-21.9°). There were no reports of acetabular protrusion, acetabular component osteolysis accompanied by radiolucency and location change, or a significant change in cup angle. A total of 36 femoral components were implanted in neutral alignment, and 3 cases were implanted in varus alignment (mean, 4.2°; range,

TABLE 2. Comparison of the perioperative parameters

Parameters	MI-THA	BHA	<i>p</i> value
Duration of operation (minutes)	70 (50-115)	46 (30-75)	.002*
Total skin incision (cm)	11.6 (8.9-17.1)	15.1 (14.2-17.3)	.078
Blood loss (ml)	920.9 (450-1,450)	891.8 (420-1,410)	.562
Intraoperative	372.2 (248-610)	315.2 (202-535)	.421
Postoperative	548.7 (202-840)	576.6 (218-875)	.526
H/V removal (days)	1.9 (0-5)	1.8 (0-5)	.856
Hemoglobin (mg/dl) change	2.6 (1.2-4.6)	2.2 (1.1-4.1)	.921
Preoperative Hb	11.6 (9.2-15.2)	11.4 (9.1-14.9)	.816
Postoperative Hb	9.0 (7.1-13.3)	9.2 (6.9-12.8)	.798
Transfusion (No of Units)	1.1 (0-3)	0.9 (0-3)	.878
Ambulation by walker or crutch (days)	2.3 (1-7)	5.3 (1-12)	.045*
Hospital stay (days)	15.1 (9-21)	16.6 (9-25)	.765
Preoperative period	4.1 (0-15)	4.8 (0-18)	.804
Postoperative period	11.0 (3-21)	11.8 (2-25)	.820

*Statistically significant difference. MI: minimal invasive, THA: total hiparthroplasty, BHA: bipolar hemiarthroplasty, Hb: hemoglobin.

3.6-4.5°). Mean LLD was 0.2 cm (range, 0-1.1 cm), and no significant vertical subsidence or localized osteolysis was reported. In the conventional BHA group, there was one case of stem loosening, which was treated by revision surgery and conversion to THA at another institute. There were 12 cases with articular cartilage narrowing and 3 cases with acetabular bony erosion. One of these three cases underwent THA conversion surgery.

In the MI THA group, two patients had dislocations at 2 and 3 months postoperatively, but no recurrent dislocation occurred after closed reduction. In the BHA group, no dislocation occurred, but one patient had a periprosthetic fracture 11 months postoperatively and was treated by use of cerclage wiring. No serious complications, such as infection, nerve injury, periprosthetic fracture during the operation, or deep vein thrombosis, occurred in either group (Table 5).

TABLE 3. Functional status in patients with one- and two-incision minimally invasive total hip arthroplasty (THA) at last follow-up

Outcomes	MI-THA		BHA		p value
	Mean	SD	Mean	SD	
HHS					
Pain	40.65	3.60	36.05	9.02	.004*
Function	39.02	7.21	35.72	6.00	.034*
Deformity	3.75	1.91	3.20	1.64	.346
ROM	4.50	0.73	4.55	0.61	.350
Total	88.30	10.20	80.39	13.88	.006*
WOMAC					
Pain	5.74	2.16	6.83	2.17	.011*
Stiffness	2.41	0.86	2.32	0.81	.638
Function	20.07	3.51	23.25	4.87	.002*
Total	28.75	5.26	32.47	7.25	.012*

*Statistically significant difference. MI: minimal invasive, THA: total hip arthroplasty, BHA: bipolar hemiarthroplasty, HHS: Harris hip score, ROM: range of motion, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index, SD: standard deviation.

TABLE 4. Activities of daily living (ADL) scale

ADL scale	MI-THA		BHA		p value (Last follow-up)
	Pre-injury (cases)	Last follow-up (cases)	Pre-injury (cases)	Last follow-up (cases)	
0	38	35	36	27	.372
1	4	5	4	7	.757
2	2	3	1	4	.673
3	0	0	0	1	
4	0	1	0	1	1.000
5	0	0	0	1	
6	0	0	0	0	
Average	0.18	0.34	0.15	0.66	0.533

MI: minimal invasive, THA: total hip arthroplasty, BHA: bipolar hemiarthroplasty, ADL: activities of daily living.

DISCUSSION

This study was undertaken to determine the relative merits of MI two-incision THA and conventional BHA with respect to the treatment of displaced femoral neck fractures in active elderly patients. The study showed that MI two-incision THA provides better hip function than does conventional BHA without increasing complications and morbidities in relatively active, independent elderly patients with a displaced femoral neck fracture. However, the present study had several limitations that require consideration. First, the study was inherently limited by its retrospective case-controlled nature. Second, we only enrolled patients who met the inclusion criteria. Third, follow-up durations were different in the two study groups because MI two-incision THA was used first to treat femoral neck fractures at our institution from 2003.

Unipolar hemiarthroplasty was first introduced in the 1940s,¹⁷ and the salvage operations devised by Moore¹⁸ and Thompson¹⁹ were introduced for femoral neck fracture nonunion in the 1950s. In 1974, Bateman²⁰ and Giliberty²¹ introduced BHA as a means of overcoming complications,

TABLE 5. Peri-operative complications of the hip arthroplasties

Complications	MI-THA (n=44)	BHA (n=41)
Intraoperative fracture	0	0
Dislocation	2	0
Infection	0	0
Hematoma	0	0
Nerve palsy	0	0
Phlebitis	0	0
Embolism	0	0
UTI	1	1
GI	0	1
Cardiac	0	1
Pulmonary	2	1
Cerebrovascular	0	0

MI: minimal invasive, THA: total hip arthroplasty, BHA: bipolar hemiarthroplasty, UTI: urinary tract infection, GI: gastrointestinal.

such as pain, acetabular cartilage wear, and acetabular protrusion. However, in 1980, Long and Knight²² concluded that the Bateman prosthesis had no benefit over the Moore prosthesis in elderly patients. Langan et al.²³ reported that 86% of acetabular cups showed no motion at 1 year postoperatively after Giliberty BHA, and that consequently acetabular cup wear and femoral head dislocation followed. In addition, Coleman et al.²⁴ converted 10 of 31 cases from BHA to THA owing to acetabular cartilage wear. In particular, more acetabular cartilage wear was caused by more activities after 5 postoperative years, and several studies have described that this is due to increased motion of the outer pole and reduced motion of the inner pole.⁸ Furthermore, Coleman et al.²⁴ reported that bone absorption around stems was caused by polyethylene particles produced by repeated contact between the outer portion of the bipolar head and the neck portion of the stem. Similar complaints, such as of continued groin pain, resulting from cartilage wear in unipolar hemiarthroplasty have been reported in BHA. Beckenbaugh et al.²⁵ reported that only 45.5% of cases treated by BHA achieved excellent results owing to groin pain and acetabular osteolysis.⁶ Therefore, to lower the risk of groin pain, THA was suggested for the treatment of femoral neck fractures.

In terms of acetabular and femoral component fixation in THA, cementless, cemented, or hybrid types can be used. In elderly patients with osteoporosis, a cementless prosthesis can provide initial stability and immediate weight-bearing ambulation. However, fixation with cement makes reoperation more difficult and can cause osteonecrosis owing to obstruction of the arteries feeding the metaphysis. In addition, the heat produced by polymerization has cytotoxic and lipolytic effects. Furthermore, blood loss might be increased because of the time required for cement placement, and cemented prostheses are inadequate for minimally invasive surgery. On the other hand, cementless THA can avoid these complications. In the present study, initial stability of the cementless stems was achieved (even in elderly patients with osteoporosis) by using preventive wiring to the lesser trochanter before reaming and tight stem fixation.

Compared with hemiarthroplasty, THA has the disadvantages of morbidity, early dislocation, and a longer operation time,¹⁰ and previous studies have shown that patients treated with THA for a femoral neck fracture dislocate at a higher rate than do patients treated electively with THA for arthritis.^{1,26} Lu-Yao et al.² reviewed articles published from 1975 to 1990 on the use of arthroplasties for the treatment of displaced femoral neck fractures. They found a significant difference in the dislocation rate between arthroplasties over the short term: 2.1% (range, 1.1-7.4%) for unipolar hemiarthroplasty, 10.7% (range, 0.0-17.9%) for THA, and 2.9% (range, 1.7-4.1%) for BHA. Iorio et al.²⁷ reported a 5 times higher dislocation rate for femoral neck fractures treated by THA than for osteoarthritis treated by THA. Lee et al.²⁶ found that 10% of 126 consecutive patients treated with THA for acute femoral

neck fracture subsequently dislocated. The authors concluded that THA appears to offer a more long-lasting treatment with better functional outcomes but with higher rates of complications, such as dislocation. Therefore, MI two-incision THA has been adopted to overcome dislocation problems after hip arthroplasty.

Several benefits such as early recovery and a low incidence of dislocation may result from a minimally invasive approach to the muscle and the joint capsule. Several reports state that the two-incision technique described by Mears and Berger²⁸⁻³⁰ has higher rates of complications and reoperation than does the conventional technique. As we described above, we used the intermuscular interval between the gluteus medius and tensor fascia lata, which avoids the risk of injuring the lateral femoral cutaneous nerve. The lateral decubitus and anterolateral approach provides better visualization and orientation of the acetabulum and thus obviates the need for fluoroscopy for acetabular component implantation. With a patient in the lateral decubitus position with the hip flexed and adducted, the intermuscular interval between the gluteus medius and piriformis is better visualized, which enables the operator to avoid muscle damage and surgical instrument impingement during femoral stem insertion. In this study, 2 (4.5%) of the 44 cases had one episode of dislocation, but there were no recurrences and ambulation could be started at an average of 2.3 days (range, 1-7 days). Other complications, such as infection, nerve injury, and intraoperative periprosthetic fractures, were not present.

In the present study, no significant differences were observed between MI two-incision THA and conventional BHA in terms of average blood loss, hemoglobin change, and the amount of transfusion, which means that although MI two-incision THA took longer, the fewer muscle and other soft injuries reduced blood loss. Furthermore, we consider that this reduced level of soft tissue injuries, especially short external rotators and reduced groin pain, may explain why the HSS, WOMAC, and ADL scores were better in the MI THA group.

In this study, better early clinical outcomes were obtained, without increased morbidity, with the use of MI two-incision THA compared with conventional BHA. Our results can be applied to the treatment of patients over the age of 60, whose pre-injury activities were almost normal. Therefore, we find that MI two-incision THA can be considered a primary treatment method for femoral neck fractures given proper instrument preparation and operator experience.

REFERENCES

1. Papandrea RF, Froimson MI. Total hip arthroplasty after acute displaced femoral neck fractures. *Am J Orthop (Belle Mead NJ)* 1996;25:85-8.
2. Lu-Yao GL, Keller RB, Littenberg B, Wennberg JE. Outcomes after displaced fractures of the femoral neck. A meta-analysis of one hundred and six published reports. *J Bone Joint Surg Am*

- 1994;76:15-25.
3. Cabanela ME. Bipolar versus total hip arthroplasty for avascular necrosis of the femoral head. A comparison. *Clin Orthop Relat Res* 1990;(261):59-62.
4. Baker RP, Squires B, Gargan MF, Bannister GC. Total hip arthroplasty and hemiarthroplasty in mobile, independent patients with a displaced intracapsular fracture of the femoral neck. A randomized, controlled trial. *J Bone Joint Surg Am* 2006;88:2583-9.
5. Blomfeldt R, Törnkvist H, Eriksson K, Söderqvist A, Ponzer S, Tidermark J. A randomised controlled trial comparing bipolar hemiarthroplasty with total hip replacement for displaced intracapsular fractures of the femoral neck in elderly patients. *J Bone Joint Surg Br* 2007;89:160-5.
6. Cameron HU. Mini-incisions: visualization is key. *Orthopedics* 2002;25:473.
7. Owens WD, Felts JA, Spitznagel EL Jr. ASA physical status classifications: a study of consistency of ratings. *Anesthesiology* 1978;49:239-43.
8. Katz S. Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living. *J Am Geriatr Soc* 1983;31:721-7.
9. Garden RS. Malreduction and avascular necrosis in subcapital fractures of the femur. *J Bone Joint Surg Br* 1971;53:183-97.
10. Yoon TR, Bae BH, Choi MS. A modified two-incision minimally invasive total hip arthroplasty: technique and short-term results. *Hip Int* 2006;16 Suppl 4:28-34.
11. 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;51:737-55.
12. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 1988;15:1833-40.
13. Widmer KH. A simplified method to determine acetabular cup anteversion from plain radiographs. *J Arthroplasty* 2004;19:387-90.
14. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res* 1976;(121):20-32.
15. Khalily C, Lester DK. Results of a tapered cementless femoral stem implanted in varus. *J Arthroplasty* 2002;17:463-6.
16. Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979;(141):17-27.
17. Moore AT, Bohlman HR. Metal hip joint. A case report. *J Bone Joint Surg Am* 1943;25:688-92.
18. Moore AT. Metal hip joint; a new self-locking vitallium prosthesis. *South Med J* 1952;45:1015-9.
19. Thompson FR. Two and a half years' experience with a vitallium intramedullary hip prosthesis. *J Bone Joint Surg Am* 1954;36-A: 489-502.
20. Bateman JE. Single-assembly total hip prosthesis. Preliminary report. *Orthop Dig* 1974;2:15-22.
21. Giliberty RP. A new concept of a bipolar endoprosthesis. *Orthop Rev* 1974;3:40-5.
22. Long JW, Knight W. Bateman UPF prosthesis in fractures of the femoral neck. *Clin Orthop Relat Res* 1980;(152):198-201.
23. Langan P. The Giliberty bipolar prosthesis: a clinical and radiographical review. *Clin Orthop Relat Res* 1979;(141):169-75.
24. Coleman SH, Bansal M, Cornell CN, Sculco TP. Failure of bipolar hemiarthroplasty: a retrospective review of 31 consecutive bipolar prostheses converted to total hip arthroplasty. *Am J Orthop (Belle Mead NJ)* 2001;30:313-9.
25. Beckenbaugh RD, Tressler HA, Johnson EW Jr. Results after hemiarthroplasty of the hip using a cemented femoral prosthesis. A review of 109 cases with an average follow-up of 36 months. *Mayo Clin Proc* 1977;52:349-53.
26. Lee BP, Berry DJ, Harmsen WS, Sim FH. Total hip arthroplasty for the treatment of an acute fracture of the femoral neck: long-term results. *J Bone Joint Surg Am* 1998;80:70-5.
27. Iorio R, Healy WL, Lemos DW, Appleby D, Lucchesi CA, Saleh KJ. Displaced femoral neck fractures in the elderly: outcomes and cost effectiveness. *Clin Orthop Relat Res* 2001;(383):229-42.
28. Berger RA. Mini-incisions: two for the price of one! *Orthopedics* 2002;25:472, 498.
29. Berger RA. Total hip arthroplasty using the minimally invasive two-incision approach. *Clin Orthop Relat Res* 2003;(417):232-41.
30. Berry DJ, Berger RA, Callaghan JJ, Dorr LD, Duwelius PJ, Hartzband MA, et al. Minimally invasive total hip arthroplasty. Development, early results, and a critical analysis. Presented at the Annual Meeting of the American Orthopaedic Association, Charleston, South Carolina, USA, June 14, 2003. *J Bone Joint Surg Am* 2003;85-A:2235-46.