Acta Orthop. Belg., 2008, **74**, 615-622

ORIGINAL STUDY

Uncemented total hip arthroplasty in patients less than twenty-years

Camilo RESTREPO, Thomas LETTICH, Nathan ROBERTS, Javad PARVIZI, William J. HOZACK

From the Rothman Institute of Orthopaedics at Thomas Jefferson University, Philadelphia, USA

A variety of conditions may lead to arthritis of the hip during adolescence. Although uncommon, total hip arthroplasty may occasionally be necessary for treatment of end-stage disabling arthritis of the hip in the young. There is paucity of information documenting the outcome of uncemented total hip arthroplasty in adolescents. We report our experience with total hip arthroplasty in patients under the age of twenty years.

The results of 35 consecutive total hip arthroplasties performed at our institution in 25 patients between 1993 and 2003 were reviewed. There were 17 females and 8 males with a mean age of 17.6 years (range : 13.5 to 20). All patients received a Hydroxyapatite (HA) plasma sprayed Titanium acetabular component and a tapered femoral stem proximally coated with HA. Follow-up averaged 6.6 years (range : 4.2 to 10). The underlying diagnosis was avascular necrosis (16 hips), juvenile rheumatoid arthritis (9 hips), sequelae of DDH (2 hips), spondyloepiphyseal dysplasia (2 hips), sequelae of Perthes (2 hips), osteoarthritis (2 hips), post-traumatic arthritis (1 hip), and pseudo rheumatoid chondrodysplasia (1 hip).

There was a significant improvement in function and relief of pain as measured by the Harris Hip score and SF-36. All uncemented components were found to be stable and osseo-integrated at the latest follow-up. There were no complications, or reoperations. There was one revision secondary to severe polyethylene wear. This patient was revised 10 years after the index surgery.

Uncemented total hip arthroplasty was found to confer a significant improvement in function and to have an acceptable short-term outcome in very young patients with end-stage arthritis of the hip. Longer-term follow-up is needed to assess the durability of this procedure in adolescents.

Keywords : total hip arthroplasty ; uncemented ; young patients ; adolescents.

INTRODUCTION

There are a variety of aetiological factors that may result in arthritis of the hip in the adolescents (*16,25,28,50*). Avascular necrosis of the femoral head and juvenile rheumatoid arthritis are such

■ Camilo Restrepo, MD, Post-Doctoral Senior Joint Research Fellow.

■ Thomas Lettich, BS, Joint Research Fellow.

■ Nathan Roberts, BS, Joint Research Fellow.

■ Javad Parvizi, MD, FRCS, Orthopaedic Surgeon, Professor and Vice Chair of Research.

■ William J. Hozack, MD, Orthopaedic Surgeon, Director Adult Reconstruction Fellowship.

Rothman Institute of Orthopaedics at Thomas Jefferson University, Philadelphia, USA.

Correspondence : William J. Hozack, 925 Chestnut Street, 2nd Floor, Philadelphia, Pennsylvania 19107, USA.

E-mail : research@rothmaninstitute.com

No benefits or funds were received in support of this study

conditions that may lead to disabling arthritis of the hip (*20,35*). The disability imposed by arthritis can compromise the daily living of these young patients. There are, therefore, not infrequent occasions when orthopaedic surgeons may encounter very young patients with end-stage arthritis of the hip necessitating surgical intervention.

A number of surgical treatment strategies including arthrodesis (*4,9,51,52*), resection arthroplasty (*7,40*), resurfacing arthroplasty (*1,2,22,42*), and total hip arthroplasty (THA) (*3,13,24,37,54*) are available to address end-stage arthritis of the hip in adolescents (*5,8,34,44,46*). Hip resection arthroplasty and arthrodesis are functionally unappealing and mostly unacceptable options for these patients (*7,40,45, 51*). The high activity level, repetitive loading, and excessive demand placed on the hip on the other hand lead to accelerated failure of THA in this group of very young patients. The potential for high failure rate averts many surgeons from recommending THA to this group of young patients. In one study evaluating the outcome of cemented THA in 63 patients, poor or fair outcome was observed in one-half of the patients at medium term follow-up (*53*). The conclusions of that study were that THA should be reserved for carefully selected patients for whom no alternative procedure exists.

Although compromised survivorship of THA in the young and very active patients cannot be disputed, improvements in the design of prosthesis and introduction of alternative bearing surfaces in recent years have lead to increasing number of THAs being performed in active and younger patients (*19, 21,27,41,47*). The outcome of uncemented modern generation THA for patients in their first and second decade of life is largely unknown. Based on the information from previous series (*6,10,12,14,17,32,38, 39,43,48,53*), it is difficult to ascertain the clinical outcome of THA in a very young patient subgroup, as the combined results for many ages are usually reported, with a much greater number of THAs performed in older patients.

This study was conducted to evaluate the clinical and radiographic results of modern design uncemented THA in patients less than twenty years of age.

MATERIALS AND METHODS

Demographics

Using an institutional computerised database we identified 25 patients (35 hips) who were twenty years or younger when they underwent uncemented THA between the years 1993 to 2003. The cohort included 17 females and 8 males with a mean age of 17.64 years (range : 13.5 to 20) at the time of index operation. The mean weight of the patients was 55.6 Kg (range : 27.7 to 83.9) and the mean height for the patients in the study was 161.6 cm (range : 134.6 to 182.9).

Preoperative diagnosis

The underlying diagnosis was avascular necrosis (16 hips), juvenile rheumatoid arthritis (9 hips), developmental dysplasia of the hip (2 hips), spondyloepiphyseal dysplasia (2 hips), Legg-Calves-Perthes disease (2 hips), post-traumatic arthritis (3 hips), and pseudo rheumatoid chondrodysplasia (1 hip). Rheumatoid arthritis was polyarticular in all patients.

Surgical data

All patients received regional anaesthesia during hip arthroplasty. The procedure was performed with the patient in supine position and through an anterolateral approach. An uncemented HA plasma sprayed acetabular component (Universal II, Biomet, Warsaw, IN or Trident PSL, Stryker Orthopaedics, Mahwah, NJ) and a proximally coated, tapered, collarless, femoral stem (Taperloc, Biomet or Accolade, Stryker Orthopaedics) with HA was utilised in all patients (figs 1 to 4). All components were inserted press fit and supplemental screw fixation of the acetabulum was used whenever appropriate. The bearing surface utilised was alumina ceramic on ceramic (Trident, Stryker Orthopaedics) in two hips, ceramic on cross-linked polyethylene in 22 hips, and metal on polyethylene in 11 hips. The head diameters used were 11 hips with 22 mm, 21 hips with 28 mm, and only 3 hips received a 32 mm head.

The mean operative time was 65.7 minutes (range : 50 to 95). The estimated external blood loss was 268.9 ml (range : 150 to 650). No postoperative suction drains were used. Prophylaxis for infection, namely a second generation cephalosporin (Ancef) for 24 hours, and an oral anticoagulation for six weeks were administered.

Fig. 1. — Taperloc (Biomet, Warsaw, IN) tapered uncemented stems.

Fig. 2. — Accolade (Stryker Orthopaedics, Mahwah, NJ) tapered uncemented stem.

Prior operations

Seven hips had a history of previous operations, which consisted of open reduction and internal fixation in 3 hips, synovectomies in 2 hips, osteotomies in 2 hips, and a vascularised graft in 1 hip.

Follow-up

Clinical and radiographic data on all patients were collected prospectively. Patients were contacted on regular basis, which included, in most cases, examination at three months, six months, one year, and every year thereafter. Institutional review board approval was obtained prior to review of the clinical material. Follow-up averaged 6.6 years (range : 4.2 to 10). All but 4 patients (6 hips) were followed for a minimum of four years, failure of prosthesis, or until death. These 4 patients were lost to follow-up. Their follow-up ranged from 2 months post-operatively to 2 years post-operatively. In all 4 cases the patients moved and/or changed their phone number and therefore could not be contacted.

Radiographic evaluation

Serial anteroposterior and lateral radiographs of the operated joint were reviewed to assess the position of the prosthesis, loosening and wear. Definitely loose components were defined as those that demonstrated a complete lucent line on any radiograph, femoral subsidence of 2 mm or more (*18*), or acetabular component migration or tilt (*18*). Possible loose components were defined as those with greater than 50% but less than 100% lucent line on any radiograph or those with a progressive radiolucent line. The femur was divided into seven zones (*23*) and the acetabulum into three zones (*15*) to evaluate the location of lucent lines.

Fig. 3. — Trident (Stryker Orthopaedics, Mahwah, NJ) HA plasma sprayed cup.

Fig. 4. — Trident (Stryker Orthopaedics, Mahwah, NJ) HA plasma sprayed cup, with an alumina ceramic liner insert.

Functional evaluation

Clinical outcome was measured using the Harris Hip Score for total hip arthroplasties (*36,49*), Western Ontario McMaster (WOMAC), Krackow Activity Scale (KAS), and the Short-form 36 (*30*). The KAS score allowed us to determine the level of ambulation at latest follow-up for each patient.

Statistical analysis

The changes in hip function scores were evaluated with the Wilcoxon signed rank test. Individual risk factors were analysed with the Fisher's exact test. Continuous risk factors were analysed with a two-sample t-test. A ninety-five per cent confidence level was used for all tests.

RESULTS

Functional outcome

The mean preoperative Harris Hip score was 51.9 points (range : 40.1 to 82.3) and improved to 77.3 points (range : 60 to 99) at latest follow-up ($p = 0.0017$). The SF-36 (Physical health dimension) improved from a preoperative mean of 43.5 points (range : 34.4 to 51.4) to 63.8 points (range : 35 to 100) at the latest follow-up ($p = 0.0022$). The SF-36 (Mental health dimension) improved from a preoperative mean of 58.5 points (range : 39.1 to 71.3) to 80.2 points (range : 49 to 100) at the latest follow-up ($p = 0.0005$). Significant improvement was also noted in SF-36 dimensions of Physical Function ($p = 0.0001$), Role-Physical ($p = 0.0015$), Social Functioning ($p < 0.0001$), and General Health Perceptions ($p = 0.0008$). The mean postoperative WOMAC score was 11.6 points (range : 0 to 27). The mean KAS score was 11.1 points (range : 7 to 15).

Prior to THA arthroplasty 2 patients were unable to walk, 8 patients were household ambulators and the remaining patients were limited community ambulators. All patients who could ambulate used gait aids prior to surgery. At latest follow-up, 10 patients (15 hips) could ambulate six or more blocks, 3 patients (5 hips) could ambulate fewer than six blocks, and 1 patient (1 hip) could ambulate indoors only, requiring no gait aid. Seven patients (11 hips) are currently attending undergraduate or graduate school. One of these patients is attending graduate school during the evening while working full-time during the day. Eleven patients (13 hips) currently hold full-time jobs. The positions range from lawyer to nurse midwife to web merchandiser to animator. Two patients currently are on maternity leave since they recently gave birth without any complications.

Radiographic finding

On preoperative radiographs all hips had complete loss of joint space. All femoral components were well-positioned. All except one acetabular component were placed within 35-45 degree of inclination and 10-20 degree of anteversion according to measurements done using a computer software (OrthoView® Southampton Hampshire, UK) on plain AP radiographs. One acetabular component was in a vertical position, with excessive anteversion, and in inferior position. At the final follow-up, all components were deemed to be stable and osseo-integrated. Progressive complete radiolucent lines, indicating a loose prosthesis, were not present in any hips. Incomplete radiolucent line was detected around the femoral component in one hip in Gruen zones (*18*) 1 and 7. Gross polyethylene wear, indicated by eccentric position of the femoral head, was not present in any hips. Femoral stem subsidence greater than 2 mm had not occurred in any hips.

Revisions/reoperations

At the latest follow-up of this study, one patient had undergone a bilateral polyethylene exchange due to wear at 10 years after index operation in 1993. This was done at an outside facility ; however the operation record was obtained for this study. According to the outside operation record, the liners were changed due to severe wear. There was mild to no osteolysis associated with wear in these hips. All components were well fixed and hence were retained.

DISCUSSION

Total hip arthroplasty is undisputedly a successful and safe surgical procedure with excellent long-term outcome in older patients (*11,31,33,55*). The outcome of THA in the younger patient population is not, however, equally rewarding (*5,34,44,46*). The higher failure rate of THA in the younger patients has been attributed to the high activity level and the excessive demand imposed on the prosthetic hip (*5*). A number of improvements in prosthesis design and the delivery of surgical care have been introduced in recent years to improve the longevity of the THA in general, and in the younger patients in particular. The introduction of modern generation uncemented components may be considered as one such advancement that has lead to an increasing number of THAs being performed in the younger patient population.

Uncemented THA is generally considered the prosthesis of choice for treatment of hip arthritis in young patients (*29,33,39,43*). Modern generation uncemented THA has been shown to have an excellent, and in some cases superior outcome compared to cemented THA (*12,14,17,26,53*). Majority of the studies reporting the outcome of THA in the young, however, include patients in their fifth, fourth, and third decades. There is paucity of data on the outcome of uncemented THA in adolescents who may on occasion require THA as the surgical treatment of choice. A multitude of childhood conditions may lead to end stage arthritis of the hip in the adolescents that may require surgical intervention. Juvenile rheumatoid arthritis, avascular necrosis, haemoglobinopathies, and post-traumatic arthritis are examples of some disease that may afflict the children and adolescents. Despite improvements and recent refinements in medical treatment for these conditions and juvenile rheumatoid arthritis in particular, progressive joint destruction leading to severe disability may occur in some of these very young patients (*16,20,28*). Because of failure of medical therapy to control the symptoms, these patients become candidates for surgical interventions.

Although a number of surgical options such as resection arthroplasty or arthrodesis may be considered, hip arthroplasty because of its functional superiority and predictable outcome is elected for these patients. Total hip arthroplasty for adolescents has been carried out in some centers (*5,8,34,44,46*). An early study by Torchia *et al* (*53*) reported on the outcome of 63 consecutive cemented THAs in 50 adolescent patients. The study demonstrated that the probability of failure (defined as revision or symptomatic loosening) increased steadily over time and reached 45% after 15 years. The probability of radiographic loosening after 15 years was 60% for the acetabular component and 20% for the

femoral component. A number of specific variables were associated with a significantly higher probability of failure, which included a history of more than one previous procedure involving the hip, unilateral arthroplasty, previous trauma involving the hip, the absence of other disease that limited function of the ipsilateral lower extremity, a high postoperative level of activity, and a preoperative weight of more than 60 Kg. The outcome was considered to be excellent in 10 hips (19%), good in 16 (31%), fair in one (2%), and poor in 25 (48%). Most of the poor results were due to symptomatic loosening of the acetabular component. Based on their findings, the authors concluded that total hip arthroplasty in adolescents should be reserved for carefully selected patients for whom alternative procedures are contraindicated or unacceptable. As all the patients in that study received cemented THA and the majority of failures related to the cemented acetabulum, the authors recommended that fixation of the acetabular component with cement should not be performed in these very young patients.

To our knowledge, there has been no specific study evaluating the outcome of uncemented THA in patients younger than 20 years. The latter provided the impetus for the current study. We have found that uncemented THA was successful in restoration of function and relief of pain for all very young patients in the cohort. A large number of patients became able to ambulate independently and were able to perform daily activities including attending school. At short term follow-up there were no complications, failures, or reoperations. At time of this report there was only one revision surgery and that was due solely to severe polyethylene wear. Intraoperatively both components were found to be well fixed and stable. Although these findings may appear encouraging, longer term follow-up is needed to confirm or refute the longevity of THA in adolescents. Nonetheless, early failures such as fractures and early loosening that had occurred in some patients in the study by Torchia *et al* (*53*) did not occur in this patient group.

There is a multitude of reasons that may explain these encouraging early findings. First and perhaps foremost relates to the fact that all of these patients received modern generation of uncemented, and not cemented, prosthesis. The tapered femoral components utilised because of their geometry, can be press fit with minimal risk of fracture or subsequent subsidence. The second is that the study spanned over a relatively short and very recent time period and benefited from numerous improvements in surgical and anaesthesia techniques, and implant design. Third, a large number of the patients in this series with juvenile rheumatoid arthritis had polyarticular disease that limited their activity level and the demand that they may place on the prosthesis. The underlying diagnosis of inflammatory arthritis has been shown to confer a beneficial influence on the survivorship of hip prosthesis (*53*). Finally, the use of alternative bearing surface such as alumina ceramic on ceramic, although used only in 2 patients, may have positively impacted the outcome in the long term by minimising the wear of the bearing surface and subsequent failure. The premise that the alternative bearing surfaces do reduce wear has now prompted us to routinely utilise alumina ceramic on ceramic bearing surface in younger patients, although other alternatives such as alumina ceramic on cross-linked polyethylene or metal on metal bearing surface also remain. The wear characteristics of metal on metal bearing surface has been demonstrated to be excellent. However, because of the concern with metal hypersensitivity and the unknown long term effect of released metal ions, we reserve the metal on metal bearing surface to very few select patients and do not utilise that bearing surface frequently. In addition, most of the alternative bearing surfaces such as ceramic on ceramic or metal on metal became available during the latter years of this study which explains the low utilisation of these bearing surfaces in this cohort.

This study suffers some limitations. This is a retrospective study with all the innate shortcomings of such study design. The cohort consists of a group of patients with a number of diagnoses that may confound the outcome particularly in the long-term. Finally, this study reports the outcome of THA at a relatively short follow-up. Despite the aforementioned shortcomings, the study possesses some strength. It reports the outcome of uncemented THA with a modern generation tapered femoral

stem in a relatively large number of adolescent patients from a single institution.

RERERENCES

1. **Adili A, Trousdale RT.** Femoral head resurfacing for the treatment of osteonecrosis in the young patient. *Clin Orthop* 2003 ; 417 : 93-101.
2. **Amstutz HC, Su EP, Le Duff MJ.** Surface arthroplasty in young patients with hip arthritis secondary to childhood disorders. *Orthop Clin North Am* 2005 ; 36 : 223-230.
3. **Arden GP, Ansell BM, Hunter MJ.** Total hip replacement in juvenile chronic polyarthritis and ankylosing spondylitis. *Clin Orthop* 1972 ; 84 : 130-136.
4. **Beaule PE, Matta JM, Mast JW.** Hip arthrodesis : current indications and techniques. *J Am Acad Orthop Surg* 2002 ; 10 : 249-258.
5. **Bessette BJ, Fassier F, Tanzer M *et al.*** Total hip arthroplasty in patients younger than 21 years : a minimum, 10-year follow-up. *Can J Surg* 2003 ; 46 : 257-262.
6. **Bsila RS, Inglis AE, Ranawat CS.** Joint replacement surgery in patients under thirty. *J Bone Joint Surg* 1976 ; 58-A : 1098-1104.
7. **Cabanela ME.** The painful young adult hip : surgical alternatives. *Perspect Orthop Surg* 1990 ; 1 : 1-22.
8. **Cage DJ, Granberry WM, Tullos HS.** Long-term results of total arthroplasty in adolescents with debilitating polyarthropathy. *Clin Orthop* 1992 ; 283 : 156-162.
9. **Callaghan JJ, Brand RA, Pedersen DR.** Hip arthrodesis. A long-term follow-up. *J Bone Joint Surg* 1985 ; 67-A : 1328-1335.
10. **Callaghan JJ, Forest EE, Sporer SM *et al.*** Total hip arthroplasty in the young adult. *Clin Orthop* 1997 ; 344 : 257-262.
11. **Charnley J, Halley DK.** Rate of wear in total hip replacement. *Clin Orthop* 1975 ; 112 : 170-179.
12. **Collis DK.** Long-term (twelve to eighteen-year) follow-up of cemented total hip replacements in patients who were less than fifty years old. A follow-up note. *J Bone Joint Surg* 1991 ; 73-A : 593-597.
13. **Colville J, Raunio P.** Total hip replacement in juvenile rheumatoid arthritis. Analysis of 59 hips. *Acta Orthop Scand* 1979 ; 50 : 197-203.
14. **Cornell CN, Ranawat CS.** Survivorship analysis of total hip replacements. Results in a series of active patients who were less than fifty-five years old. *J Bone Joint Surg* 1986 ; 68-A : 1430-1434.
15. **DeLee JG, Charnley J.** Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop* 1976 ; 121 : 20-32.
16. **Dequeker J, Mardjuadi A.** Prognostic factors in juvenile chronic arthritis. *J Rheumatol* 1982 ; 9 : 909-915.
17. **Dorr LD, Luckett M, Conaty JP.** Total hip arthroplasties in patients younger than 45 years. A nine- to ten-year follow-up study. *Clin Orthop* 1990 ; 260 : 215-219.
18. **Engh CA, Massin P, Suthers KE.** Roentgenographic assessment of the biologic fixation of porous-surfaced femoral components. *Clin Orthop* 1990 ; 257 : 107-128.
19. **Fenollosa J, Seminario P, Montijano C.** Ceramic hip prostheses in young patients : a retrospective study of 74 patients. *Clin Orthop* 2000 ; 379 : 55-67.
20. **Flato B, Lien G, Smerdel A *et al.*** Prognostic factors in juvenile rheumatoid arthritis : a case-control study revealing early predictors and outcome after 14.9 years. *J Rheumatol* 2003 ; 30 : 386-393.
21. **Garino JP.** Modern ceramic-on-ceramic total hip systems in the United States : early results. *Clin Orthop* 2000 ; 379 : 41-47.
22. **Grecula MJ.** Resurfacing arthroplasty in osteonecrosis of the hip. *Orthop Clin North Am* 2005 ; 36 : 231-242.
23. **Gruen TA, McNeice GM, Amstutz HC.** "Modes of failure" of cemented stem-type femoral components : a radiographic analysis of loosening. *Clin Orthop* 1979 ; 141 : 17-27.
24. **Gudmundsson GH, Harving S, Pilgaard S.** The Charnley total hip arthroplasty in juvenile rheumatoid arthritis patients. *Orthopedics* 1989 ; 12 : 385-388.
25. **Hallel T, Salvati EA.** Septic arthritis of the hip in infancy : end result study. *Clin Orthop* 1978 ; 132 : 115-128.
26. **Halley DK, Wroblewski BM.** Long-term results of low-friction arthroplasty in patients 30 years of age or younger. *Clin Orthop* 1986 ; 211 : 43-50.
27. **Hamadouche M, Boutin P, Daussange J *et al.*** Alumina-on-alumina total hip arthroplasty : a minimum 18.5-year follow-up study. *J Bone Joint Surg* 2002 ; 84-A : 69-77.
28. **Harris WH.** Etiology of osteoarthritis of the hip. *Clin Orthop* 1986 ; 213 : 20-33.
29. **Harris WH, Penenberg BL.** Further follow-up on socket fixation using a metal-backed acetabular component for total hip replacement. A minimum ten-year follow-up study. *J Bone Joint Surg* 1987 ; 69-A : 1140-1143.
30. **Jones JG, Leighton F.** Comparison of WOMAC with SF-36 for OA of the knee or hip. *Ann Rheum Dis* 2002 ; 61 : 182-183.
31. **Kavanagh BF, Dewitz MA, Ilstrup DM *et al.*** Charnley total hip arthroplasty with cement. Fifteen-year results. *J Bone Joint Surg* 1989 ; 71-A : 1496-1503.
32. **Kerboull L, Hamadouche M, Courpied JP *et al.*** Long-term results of Charnley-Kerboull hip arthroplasty in patients younger than 50 years. *Clin Orthop* 2004 ; 418 : 112-118.
33. **Kim YH, Oh SH, Kim JS *et al.*** Contemporary total hip arthroplasty with and without cement in patients with osteonecrosis of the femoral head. *J Bone Joint Surg* 2003 ; 85-A : 675-681.
34. **Klassen RA, Parlasca RJ, Bianco AJ Jr.** Total joint arthroplasty. Applications in children and adolescents. *Mayo Clin Proc* 1979 ; 54 : 579-582.
35. **Kruczynski J.** Avascular necrosis of the proximal femur in developmental dislocation of the hip. Incidence, risk

factors, sequelae and MR imaging for diagnosis and prognosis. *Acta Orthop Scand* 1996 ; 268 (Suppl) : 1-48.

36. Mahomed NN, Arndt DC, McGrory BJ *et al.* The Harris hip score : comparison of patient self-report with surgeon assessment. *J Arthroplasty* 2001 ; 16 : 575-580.

37. Maric Z, Haynes RJ. Total hip arthroplasty in juvenile rheumatoid arthritis. *Clin Orthop* 1993 ; 290 : 197-199.

38. McAuley JP, Szuszczewicz ES, Young A *et al.* Total hip arthroplasty in patients 50 years and younger. *Clin Orthop* 2004 ; 418 : 119-125.

39. McLaughlin JR, Lee KR. Total hip arthroplasty in young patients. 8- to 13-year results using an uncemented stem. *Clin Orthop* 2000 ; 373 : 153-163.

40. Milgram JW, Rana NA. Resection arthroplasty for septic arthritis of the hip in ambulatory and nonambulatory adult patients. *Clin Orthop* 1991 ; 272 : 181-191.

41. Mittelmeier H, Heisel J. Sixteen-years' experience with ceramic hip prostheses. *Clin Orthop* 1992 ; 282 : 64-72.

42. Nelson CL, Walz BH, Gruenwald JM. Resurfacing of only the femoral head for osteonecrosis. Long-term follow-up study. *J Arthroplasty* 1997 ; 12 : 736-740.

43. Parvizi J, Sullivan T, Duffy G *et al.* Fifteen-year clinical survivorship of Harris-Galante total hip arthroplasty. *J Arthroplasty* 2004 ; 19 : 672-677.

44. Roach JW, Paradies LH. Total hip arthroplasty performed during adolescence. *J Pediatr Orthop* 1984 ; 4 : 418-421.

45. Roberts CS, Fetto JF. Functional outcome of hip fusion in the young patient. Follow-up study of 10 patients. *J Arthroplasty* 1990 ; 5 : 89-96.

46. Ruddlesdin C, Ansell BM, Arden GP *et al.* Total hip replacement in children with juvenile chronic arthritis. *J Bone Joint Surg* 1986 ; 68-B : 218-222.

47. Sedel L. Evolution of alumina-on-alumina implants : a review. *Clin Orthop* 2000 ; 379 : 48-54.

48. Sochart DH, Porter ML. Total hip arthroplasty with cement in patients less than twenty years old. Long-term results. *J Bone Joint Surg* 1998 ; 80-A : 1397-1398.

49. Soderman P, Malchau H. Is the Harris hip score system useful to study the outcome of total hip replacement ? *Clin Orthop* 2001 ; 384 : 189-197.

50. Soren A, Klein WHuth F. Microscopic comparison of the synovial changes in posttraumatic synovitis and osteoarthritis. *Clin Orthop* 1976 ; 121 : 191-195.

51. Sponseller PD, McBeath AA, Perpich M. Hip arthrodesis in young patients. A long-term follow-up study. *J Bone Joint Surg* 1984 ; 66-A : 853-859.

52. Stover MD, Beaule PE, Matta JM *et al.* Hip arthrodesis : a procedure for the new millennium ? *Clin Orthop* 2004 ; 418 : 126-133.

53. Torchia ME, Klassen RA, Bianco AJ. Total hip arthroplasty with cement in patients less than twenty years old. Long-term results. *J Bone Joint Surg* 1996 ; 78-A : 995-1003.

54. Witt JD, Swann M, Ansell BM. Total hip replacement for juvenile chronic arthritis. *J Bone Joint Surg* 1991 ; 73-B : 770-773.

55. Wroblewski BM, Taylor GW, Siney P. Charnley low-friction arthroplasty : 19- to 25-year results. *Orthopedics* 1992 ; 15 : 421-424.