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ORIGINAL ARTICLE

Risk factors for poor hip flexion after total hip arthroplasty for the treatment of ankylosing spondylitis a multivariate analysis

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Abstract The purpose of this study is to investigate the clinical and radiographic results of total hip arthroplasty (THA) for the treatment of ankylosing spondylitis (AS) and to evaluate the effects of patient, prosthesis design, and surgical technique-related risk factors on postoperative functional results. We retrospectively reviewed the clinical and radiographic results of THA performed in 167 hips for 100 patients with AS. The average follow-up period was 54.8 months (range, 32–129 months). The hip passive-flexion arc averaged only 0 ° (0–40.0 °) before surgery, compared with 100.0 ° (85.0–110.0 °) at the most recent follow-up examination ($P<0.001$). Multivariate regression demonstrated that significant variables for postoperative hip flexion were degree of preoperative flexion contracture, preoperative level of C-reactive protein, use of a 32-mm femoral head, and postoperative heterotopic ossification. In patients with AS with severe pain, limited motion and posture, as well as deformity, the overall outcomes after THA were found to be favorable with an encouraging midterm prosthetic survivorship, a low complication rate and a high level of patients' satisfaction. It seemed these patients were particularly predisposed to relative poor range of motion of the involved hips after THA which was closely related to patients' satisfaction. The surgeons should pay careful attention to all possible risk factors perioperatively and develop a comprehensive treatment regimen.

Keywords Ankylosing spondylitis · Arthroplasty · Hip · Risk factor

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Introduction

Ankylosing spondylitis (AS) is a chronic progressive rheumatic disease characterized by inflammation of the sacroiliac joints, spine, and peripheral joints. The leg joints are affected at a relatively high rate, and cases involving the hip joint account for 25 to 50 % of AS cases [1–5]. With regard to the significant and central function of the hip, impairment of hip functioning is clearly related to restricted body function in AS patients [6]. In addition, hip involvement cannot only affect the patients in physical status but also in employability, psychosocial status, and comprehensive quality of life [7]. For severe gait and posture disturbances associated with pain and contracture or deformity of the end-stage hip joint, total hip arthroplasty (THA) is an effective treatment. Hamdi et al. [8] showed that a limited flexion/extension of the hip and a destructive radiological pattern (mimicking the osteoarthritis radiological pattern) may be risk factors for hip replacement surgery.

The results of THA in patients with AS have been widely reported [2–4, 9]. We conducted a study to analyze the midterm clinical and radiographic results of THA in patients with AS. In addition, several authors observed that limited hip flexion was relatively common among patients with AS after THA [5, 9]. We hypothesized that the patients with AS might have poor hip flexion after THA and the secondary goal of the study was to seek some patient, prosthesis design, or surgeon-related factors that significantly contribute to this phenomenon.

Materials and methods

We conducted a retrospective review of consecutive THAs performed to treat AS between September 2001 and January 2009 in 181 hips in 107 patients. At the most recent follow-up examination, 167 hips (100 patients) were available for evaluation after a minimum follow-up period of 2 years. The average follow-up period was 54.8 months (range, 32–129 months). There were 19 women (19 %) and 81 men (81 %). The average age of all patients was 15.3 years (range, 10–42 years) at the onset of AS and 36.4 years (range, 17–69 years) at the time of THA. The average interval between AS onset and surgery was 12.0 years (8.0–20.0 years). The mean body mass index was 22.4 (range, 13.7–34.1). No patient had had any prior surgery on the involved hip. The indications for THA were severe pain, limited motion and posture, and deformity.

Prosthesis selection

All acetabular components used were cementless cups and were routinely implanted using the press-fit technique. Cementless stems were used in 134 (80.2 %) hips, and cemented stems were used in 33 (19.8 %) hips. We used a ceramic-on-ceramic bearing surface in 84 hips (50.3 %), a ceramic-on-polyethylene bearing surface in 54 hips (32.3 %), and cobalt–chrome heads on a polyethylene bearing surface in 29 hips (17.3 %).

Clinical and radiographic evaluation

Patients were evaluated clinically, using the Harris hip score system [10] by two independent observers. The two independent observers were not involved in performing the arthroplasties. All patients were monitored clinically and radiographically on an outpatient basis at 3, 6, and 1 year after surgery and biannually thereafter. The Harris hip score is based on assessment of pain, function, deformities, and range of motion (ROM). On the 100-point scale, a score of 90 points or more is defined as an excellent outcome; 80 to 89 points, a good outcome; 70 to 79 points, a fair outcome; and 70 points or less, a poor outcome.

We documented the passive-sum ROM, which refers to the sum of flexion, extension, abduction, adduction, internal rotation, and external rotation. Ankylosis of the hip was defined during physical examination as a total loss of hip motion [11]. The erythrocyte sedimentation rate (ESR) and the level of C-reactive protein (CRP) were also routinely measured. No patients received prophylaxis against heterotopic ossification (HO). Patients' satisfaction was evaluated using a self-administered four-category scale (very satisfied, somewhat satisfied, somewhat dissatisfied, and very dissatisfied).

Serial anteroposterior (AP) and translateral hip radiographs were examined for evidence of osteolysis or loosening before THA and at follow-up visits. The bone–prosthesis interface was evaluated according to the zone system described by Gruen et al. [12] and DeLee and Charnley [13] for the femoral side and the acetabular side, respectively. Loosening of the acetabular cup was defined as a change in cup position exceeding 2 mm, a change in cup angle exceeding 3 °, or the detection of a radiolucent line thicker than 2 mm around a cup. Periprosthetic cystic or scalloped lesions with a diameter of >2 mm that had not been present on radiographs obtained immediately after surgery were defined as periprosthetic osteolysis [14, 15]. Loosening of cemented stems was defined according to the criteria of Harris et al. [16], whereas loosening of cementless stems was defined as described by Engh et al. [17]. We used the classification described by Brooker et al. [18] for the evaluation of postoperative HO. Acetabular protrusion, when present, was graded according to the criteria of Sotelo-Garza and Charnley [19], which uses the rim of the pelvis, taken as a projection of the upper margin of the pubic ramus, as a reference. Acetabular cup inclination angle and anteversion angle were measured by the method described by Widmer [20], and 40±10 ° for inclination and 15±10 ° for anteversion were regarded as in the safe zone proposed by Lewinnek et al. [21]. The obturator foramen ratio (OFR) was measured on pelvic AP radiographs [22].

Statistical analysis

Data were statistically analyzed using SPSS software for Windows (version 15; IBM, Armonk, NY, USA). Descriptive analyses for categorical variables were based on percentages and frequencies and for continuous variables on mean and standard deviation (SD) or median and quartile (25–75 %) if the data were skewed. The preoperative and final follow-up Harris score and the arc of passive-sum ROM and flexion were compared using the Wilcoxon signed rank test. The correlations between continuous variables and ordinal variables were determined using Pearson correlation analysis and Spearman rank correlation analysis by correlation coefficient (r), respectively.

Based on postoperative hip passive-flexion arc, we classified hips into the good flexion subgroup (>90 °) and poor flexion subgroup (≤90 °). We performed a univariate analysis for assessing whether each variable of interest was associated with poor hip flexion after THA, using independent sample Student's t tests or Mann–Whitney tests for continuous variables and chi-squared tests for dichotomous variables, respectively, as summarized in Table 1. These variables were divided into three categories, including patient-related factors, prosthesis-related factors, and factors related to surgical technique and were compared between the two subgroups to determine where statistical differences existed. The patient-related factors included sex, age at onset of AS, age at THA, interval between onset and treatment, body mass index, degree of preoperative flexion contracture, degree of preoperative passive hip flexion, preoperative hip ROM, acetabular protrusion, ankylosis, femoral neck-shaft angle, OFR, preoperative ESR, preoperative CRP level, and postoperative HO. The prosthesis-related factors included use of a 32-mm

Table 1 Results of univariate and multivariate statistical analysis between hip flexion outcome groups

Variables	Poor flexion subgroup (n=68)	Good flexion subgroup (n=99)	Univariate analysis P value	Multivariate analysis OR (95 % CI)	P value
Patient-related factors					
Female sex	13.2 %	22.2 %	0.142		
Body mass index	22.1±8.2	22.5±4.6	0.528		
Age at onset of ankylosing spondylitis, years	21.7±8.2	21.6±8.1	0.944		
Age at total hip arthroplasty, years	37.9±12.3	35.4±11.4	0.171		
Treatment duration, years	12.0 (8.0–24.0)	12.0 (7.0–20.0)	0.135		
Degree of preoperative flexion contracture (°)	21.9±18.9	14.7±17.2	0.011*	0.976 (0.957–0.996)	0.018
Degree of preoperative passive hip flexion (°)	16.0±26.4	27.6±36.0	0.025*		
Preoperative hip range of motion (°)	23.3±39.3	43.6±57.7	0.012*		
Ankylosis	64.7 %	51.5 %	0.091		
Acetabular protrusion	4.4 %	12.1 %	0.087		
Postoperative heterotopic ossification	64.3 %	35.7 %	<0.001*	0.237 (0.106–0.530)	<0.001
Erythrocyte sedimentation rate, mm/h	29.9±25.8	26.8±21.3	0.395		
C-reactive protein, mg/L	31.0±37.8	20.6±18.0	0.019*	0.981 (0.968–0.994)	0.004
Femoral neck-shaft angle (°)	141.9±13.2	139.0±16.2	0.211		
Obturator foramen ratio	1.38±0.26	1.30±0.26	0.058		
Prosthesis-related factors					
32-mm femoral head	25.4 %	74.6 %	0.001*	3.902 (1.817–8.377)	<0.001
Elevated liner	49.4 %	50.6 %	0.023*		
Factors related to surgical technique					
Cup anteversion angle (°)	25.2±9.8	24.8±9.5	0.771		
Cup inclination angle (°)	40.2±9.0	42.0±6.9	0.149		

Percent given for dichotomous variables; mean±SD given for continuous variables

*Statistically significant

femoral head and an elevated liner. The factors related to surgical technique included postoperative inclination angle and anteversion angle of acetabular cups. Then, a multivariate logistic regression model was used in assessment of risk factors identified as significant in the analysis and the odds ratio with 95 % confidence intervals (CIs) and the associated P value were determined. All reported P values are two-tailed with an alpha of 0.05. The area under the curve (AUC) value was calculated to assess the accuracy of the model.

Results

Clinical assessment

The average Harris hip score increased from 14.0 (9.0–23.0) before surgery to 89.0 (83.0–95.0) at the latest follow-up examination (P<0.001). Results were excellent for 84 hips (50.3 %), good for 60 (35.9 %), fair for 13 (7.8 %), and poor for 10 (6.0 %). At the most recent follow-up examination, only 1 hip had severe pain, 14 hips had moderately painful symptoms, and the other 152 hips had no or slight pain.

A significant improvement in the arc of passive-sum ROM and flexion was seen after THA. The passive-sum ROM averaged only 0 ° (0–60 °) before surgery, compared with 205.0 ° (185.0–220.0 °) at the most recent follow-up examination (P<0.001). The hip passive-flexion arc averaged only 0 ° (0–40.0 °) before surgery, compared with 100.0 ° (85.0–110.0 °) at the most recent follow-up examination (P<0.001). Before surgery, 154 hips (92.2 %) were unable to flex above 90 ° passively, whereas after THA, 99 hips (59.3 %) had passive hip flexion of >90 ° (P<0.001).

Before surgery, flexion contracture was present in 101 hips and averaged 25.6±14.6 ° (range, 5–70 °). After THA, 106 hips had no flexion contracture and 61 hips had an average flexion contracture of 12.6±5.8 ° (range, 5–35 °). Of those 61 hips, 46 hips retained their preoperative flexion contracture and 15 had new-onset flexion contracture. After surgery, the patients who were unable to put on their shoes represented 44 hips (26.3 %) and those who were unable to put on their shoes at ease represented 57 hips (34.1 %).

Before THA, ankylosis of hip was seen in 95 hips and acetabular protrusion was confirmed in 15 hips. The average

ESR was 28.1±23.2 mm/h (2–95 mm/h), and the average level of CRP was 24.8±28.2 mg/L (0.38–151 mg/L).

Radiographic results

The overall inclination angle and anteversion angle of acetabular cups were 41.3±7.9 ° (22.5–62.3 °) and 24.9±9.6 ° (3.4–49.0 °), respectively. Of the 167 hips, 84 (50.3 %) were outside the Lewinnek acetabular cup anteversion safe zone (82 hips>25 ° and 2 hips<5 °) and 38 (22.8 %) were outside the Lewinnek cup inclination safe zone (26 hips>50 ° and 12 hips<30 °). Among the cups, 11 (6.6 %) had an inclination angle of >50 ° and an anteversion angle of >25 ° simultaneously.

At the final follow-up evaluation, three cementless acetabular components showed partial nonprogressive radiolucencies (zones I and II) <2-mm wide. All of them were associated with a good or excellent Harris hip score and were therefore considered stable. We did not detect radiolucency around the stem or signs of migration in any hips.

Intergroup comparisons

We noted that the hip passive-flexion arc was only 96.1±15.3 ° (45–130 °) after THA. We found a statistically significant correlation between the postoperative hip passive-flexion arc and the following variables: age at THA (r=−0.193; P=0.012), interval between AS onset and treatment (r=−0.209; P=0.007), ankylosis (r=−0.225; P=0.003), degree of preoperative flexion contracture (r=−0.193; P=0.012), degree of preoperative passive hip flexion (r=0.275; P<0.001), preoperative hip ROM (r=−0.280; P<0.001), and postoperative HO (r=−0.226; P=0.003). We classified hips into the good flexion subgroup (>90 °, 99 hips) and poor flexion subgroup (≤90 °, 68 hips). The differences between them are presented in Table 1. Next, the risk factors identified as significant were introduced into a multivariate logistic regression model to allow us to observe the effect that postoperative variables inevitably have on postoperative hip flexion. The model revealed that significant variables for postoperative hip flexion were degree of preoperative flexion contracture (odds ratio [OR]=0.976; P=0.018), preoperative CRP level (OR=0.981; P=0.004), use of a 32-mm femoral head (OR=3.902; P<0.001), and postoperative HO (OR=0.237; P<0.001) (Table 1). The AUC value of the multivariate regression model was 0.765.

Patients' satisfaction

The patients who were very satisfied with the results of THA represented 82 hips (49.1 %); those who were somewhat satisfied represented 75 (44.9 %) hips. Those who were somewhat dissatisfied represented 10 (6.0 %) hips. The main causes of dissatisfaction included limited flexion and/or rotation (53 hips, 31.7 %), pain (9 hips, 5.4 %), leg-length discrepancy (7 hips, 4.2 %) as well as limp (6 hips, 3.6 %) (see Table 2).

Complications

One anterior dislocation occurred in a man in the ankylosed hip group. During revision surgery, it was confirmed that he had exaggerated cup anteversion, which was successfully treated with anteversion adjustment of the cup. The other dislocation occurred in a woman in the nonankylosed group; it was successfully treated with closed reduction. Iatrogenic sciatic nerve injuries were diagnosed in two patients, but those full resolved within 1 year. There were no deep wound infections. No hip was revised.

After surgery, 42 hips (25.1 %) demonstrated HO: Brooker class I in 29, class II in 9, and class III in 4; no hips had class IV HO. Of these 42 hips, 33 were from the preoperative ankylosed group (78.6 %); 4 hips with class III HO were in two patients with bilateral bony ankylosed hips.

Discussion

Although previously reported, research has confirmed relatively encouraging results for cemented or cementless THA in patients in AS with respect to midterm or long-term survival and patients' satisfaction [1–5, 9, 22–25], many surgeons consider it technically challenging because of the high possibility of postoperative complications such as aseptic loosening [1–5, 9], HO [5, 9, 22, 26, 27], and dislocation [22, 25]. In addition, the release and rebalancing of long-standing soft-tissue contractures and accurate placement of acetabular components in the presence of fixed pelvic rotation are technically demanding [4]. Interestingly, in contrast to previous reports, our findings did not support the notion that patients with AS undergoing THA are particularly predisposed to certain complications such as aseptic loosening, HO, and dislocation, and in fact, we found the most significant factor to be the relatively poor ROM after THA that was closely related to patients' satisfaction. However, the patients with limited flexion were mostly somewhat satisfied with the surgical results, which were closely related with the poor preoperative ROM as well as the high percentage of hip fusion.

We did not see any hips with aseptic loosening in our series. Our explanations are as follows: first, the follow-up period was relative short, being an average of <5 years. Second, there was a comparably high percentage of ceramic-bearing surface, with more than half of the hips having a ceramic-on-ceramic prosthesis. Third, AS is a Charley class C disease with a typical manifestation of poor general function status. Accordingly, the physical demands that the patience place on their hips after THA were at a relatively low level.

Table 2 Patients' satisfaction level and main causes of dissatisfaction

	No dissatisfaction (%)	Limited flexion and/or rotation (%)	Pain (%)	Leg-length discrepancy (%)	Limp (%)	Total (%)
Very satisfied	82 (49.1)	0	0	0	0	82 (49.1)
Somewhat satisfied	0	58 (34.7)	8 (4.8)	6 (3.6)	3 (1.8)	75 (44.9)
Somewhat dissatisfied	0	5 (3.0)	1 (0.6)	1 (0.6)	3 (1.8)	10 (6.0)
Very dissatisfied	0	0	0	0	0	0 (0)
Total	82 (49.1)	53 (31.7)	9 (5.4)	7 (4.2)	6 (3.6)	167 (100)

Fourth, the most significant factor was poor postoperative ROM.

Factors influencing postoperative range of motion

Joint mobility is an important factor in daily function, and normal hip active or passive ROM has been reported to usually be between 115 and 125 °. The durability and ROM of both hips are of particular importance in the relatively young and active group of patients with AS in whom decreased motion of the spine may result in increased loading and functional demands on the hip joints. However, several series have shown that THA in patients with AS has resulted in inferior hip flexion ability compared with primary THA for noninflammatory conditions. Brinker et al. [9] reported an average 82 ° of hip flexion after THA in their cohort, and Joshi et al. [5] reported that 67 % of hips had a good to excellent passive ROM. Li et al. [28] suggested that hip resurfacing may produce more improvement in ROM than THA does. In their series, the flexion–extension ROM was 118.42° in the hip-resurfacing group and 93.41 ° in the THA group. In our study, we found a significant increase in hip passive-flexion arc (100.0 ° (85.0–110.0 °) vs 0 ° (0–40.0 °); $P<0.001$), which was based on a relatively low level of hip flexion and a high percentage of hip ankylosis. After THA, only 55 (32.9 %) of the hips in our series had flexion of >90 °, and 75 patients, representing 103 hips (60.4 %), were unable to put on their shoes or had difficulty doing so.

Numerous factors play a role in determining ROM after THA and can be categorized as patient factors, prosthesis-design factors, surgical-technique factors, and rehabilitation factors. We introduced many of them into our regression model and found that significant variables for postoperative hip flexion were degree of preoperative flexion contracture, preoperative CRP level, use of a 32-mm femoral head, and postoperative development of HO. The AUC value of the multivariate regression model was 0.765, which, to some extent, was good enough to predict the poor flexion after THA. Before THA, the surgeon must evaluate all possible factors thoroughly and inform patients that there is a possibility of decreased ROM or even reankylosis after surgery. After trial reduction during surgery, joint stability should be carefully checked in every direction to prevent dislocation and impingement. Make sure to judge the tightness and compliance of soft tissue; hyper tightness around the hip should be avoided as possible. The use of a larger head size has been widely recommended, which can increase the ROM and joint stability by improving jump distance [29, 30]. An efficient, multimodal rehabilitation program is of great importance and should include an efficient analgesia regimen and active exercise therapy. The ESR and CRP level should be regularly monitored, and we suggested the use of anti-inflammatory drugs to control systemic inflammation and prevent HO [31]. The incidence of HO after THA for AS has been reported to range from 11 to 76 % [2, 3, 5, 9, 22, 25]. Our study's incidence of 25.1 % did not support the notion that all patients with AS undergoing primary THA are particularly predisposed to developing severe HO. However, the multivariate regression model showed that postoperative HO was certainly a risk factor for decreased ROM after THA (OR= 0.237; $P<0.001$). In our study, 78.6 % of hips with HO were from the preoperative ankylosed group, and four hips with class III HO were from two patients with bilateral bony ankylosed hips, which indicated that preoperative ankylosis may serve as an important clinical risk factor for postoperative HO.

Study limitations

First, our results were reported at the latest follow-up evaluation; that is, all data were collected at just a single time point. Röder et al. [32] demonstrated that functional outcome after THA was strongly associated with the passage of time. They found a time-dependent gradual decline in function, as measured by all outcome parameters, which begins at an average of 5 years after THA and continues thereafter. Before THA, only 21 % of their patients could achieve hip flexion >90 °, whereas 1 year after THA, hip flexion >90 ° was possible in 73 % of patients. They found that hip flexion range did not peak until 5 years after surgery, when 79 % of hips achieved hip flexion of >90 °. With the passage of time, Röder et al. observed a decline in ROM. Subanalysis according to Charnley classes revealed that patients in Charnley class B had the poorest preoperative and postoperative hip flexion. In our study, the average age of all patients was 36.4 years at the time of THA, and the average length of the follow-up period was 51.3 months, which was in accordance with the peak time of postoperative function reported by Röder et al. [32]. Unfortunately, we failed to make a dynamic tracing of postoperative hip ROM and therefore were unable to determine their dynamic change.

Second, the Charnley classification reflects overall health status and function level and thus can be regarded as a key demographic factor in ambulation ability. AS can be considered Charnley class C and carries the potential of deterioration. In our analysis, the preoperative ESR was abnormal (>20 mm/L) in 92 hips (55.1 %) and the CRP level was abnormal (>8 mg/L) in 113 hips (67.7 %). Both ESR and CRP level were elevated in 79 hips (47.3 %), which indicated that in nearly half of the patients, AS was possibly in the active phase. Moreover, the multivariate regression model demonstrated that the preoperative CRP level was a significant variable contributing to postoperative hip flexion (OR=0.981; P=0.004). Unfortunately, we did not determine the postoperative ESR or CRP level; AS can manifest as aggravation of damage to involved joints even after they have been treated with THA. To be more specific, the possibility of recurrence of soft-tissue contracture cannot be excluded.

Third, it was impossible to assess all risk factors for the development of limited ROM. The two greatest contributors to limited ROM are bone deformity and soft-tissue tightness, both of which can be addressed during THA. The former can be directly evaluated by comparing pre- and postoperative radiographs or even CT imaging, whereas for the latter, no quantitative clinical method has yet been developed that is effective and reliable. In addition, comprehensive and effective rehabilitation training as well as pain control can help restore good ROM. However, owing to the variability of pathologic anatomy in the hip, it is impossible to control all of these clinical variables for rigid scientific analysis, and we did not include these factors in our analysis of regression model.

In conclusion, we found in patients with AS the overall outcome of THA is favorable, with an encouraging midterm prosthetic survival rate, a low complication rate, and a high level of patient satisfaction. The only fly in the ointment was a limited postoperative ROM, which was associated with the poor general function status in this population. Multivariate regression demonstrated that significant variables for postoperative hip flexion were degree of preoperative flexion contracture, preoperative CRP level, the use of a 32-mm femoral head, and postoperative development of HO. We will continue to study the long-term survival of prostheses in THA for patients with AS, especially in the cases involving larger femoral head sizes and ceramic-bearing surfaces. A periodic survey of postoperative function status and inflammatory level will be helpful in disclosing the unique dynamic variation pattern in postoperative function in AS.

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Conflict of interest Each author certifies that he has participated in the research and this article has not been submitted to any other journal. Each author certifies that he has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article. Each author certifies that his institutional review board approved the human protocol for this investigation, that all investigations were conducted in conformity with the ethical principles of research.

References

1. Williams E, Taylor AR, Arden GP, Edwards DH (1977) Arthroplasty of the hip in ankylosing spondylitis. J Bone Joint Surg (Br) 59:393–397
2. Bisla RS, Ranawat CS, Inglis AE (1976) Total hip replacement in patients with ankylosing spondylitis with involvement of hip. J Bone Joint Surg Am 58:233–238
3. Walker LG, Sledge CB (1991) Total hip arthroplasty in ankylosing spondylitis. Clin Orthop Relat Res 62:198–204
4. Soehart DH, Porter ML (1997) Long-term results of total hip replacement in young patients who had ankylosing spondylitis. Eighteen to thirty-year results with survivorship analysis. J Bone Joint Surg Am 79:1181–1189
5. Joshi AB, Markovic L, Hardinge K, Murphy JC (2002) Total hip arthroplasty in ankylosing spondylitis: an analysis of 181 hips. J Arthroplasty 17:427–433
6. Falkenbach A, Franke A, van der Linden S (2003) Factors associated with body function and disability in patients with ankylosing spondylitis: a cross-sectional study. J Rheumatol 30:2186–2192
7. Kobelt G, Andlin-Sobocki P, Maksymowych WP (2006) Costs and quality of life of patients with ankylosing spondylitis in Canada. J Rheumatol 33:289–295
8. Hamdi W, Alaya Z, Ghannouchi MM, Haouel M, Kchir MM (2012) Associated risk factors with worse functional prognosis and hip replacement surgery in ankylosing spondylitis. Joint Bone Spine 79:94–96
9. Brinker MR, Rosenberg AG, Kull L, Cox DD (1996) Primary noncemented total hip arthroplasty in patients with ankylosing spondylitis, clinical and radiographic results at an average follow-up period of 6 years. J Arthroplasty 11:802–812
10. Harris WH (1969) 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 51:737–755
11. Bangjian H, Peijian T, Ju L (2012) Bilateral synchronous total hip arthroplasty for ankylosed hips. Int Orthop 36:697–701
12. Gruen TA, McNeice GM, Amstuts HC (1979) "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop Relat Res 141:17–27
13. DeLee JG, Charnley J (1976) Radiological demarcation of cemented sockets in total hip. Clin Orthop Relat Res 121:20–32
14. Joshi RP, Eftekhar NS, McMahon DJ, Nercessian OA (1998) Osteolysis after Charnley primary low-friction arthroplasty. A comparison of two matched paired groups. J Bone Joint Surg (Br) 80:585–590
15. Maloney WJ, Jasty M, Harris WH, Galante JO, Callaghan JJ (1990) Endosteal erosion in association with stable uncemented femoral components. J Bone Joint Surg Am 72:1025–1034
16. Harris WH, McCarthy JC Jr, O'Neill DA (1982) Femoral component loosening using contemporary techniques of femoral cement fixation. J Bone Joint Surg Am 64:1063–1067

17. Engh CA, Massin P, Suthers KE (1990) Roentgenographic assessment of the biologic fixation of porous-surfaced femoral components. Clin Orthop 257:107–128
18. Brooker AF, Bowerman JW, Robinson RA, Riley LH Jr (1973) Ectopic ossification following total hip replacement: incidence and a method of classification. J Bone Joint Surg Am 55:1629–1632
19. Sotelo-Garza A, Charnley J (1978) The results of Charnley arthroplasty of hip performed for protrusio acetabuli. Clin Orthop Relat Res 132:12–18
20. Widmer KH (2004) A simplified method to determine acetabular cup anteversion from plain radiographs. J Arthroplasty 19:387–390
21. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR (1978) Dislocations after total hip replacement arthroplasties. J Bone Joint Surg Am 60:217–220
22. Tang WM, Chiu KY (2000) Primary total hip arthroplasty in patients with ankylosing spondylitis. J Arthroplasty 15:52–58
23. Lehtimäki MY, Lehto MU, Kautiainen H, Lehtinen K, Hämäläinen MM (2001) Charnley total hip arthroplasty in ankylosing spondylitis: survivorship analysis of 76 patients followed for 8–28 years. Acta Orthop Scand 72:233–236
24. Sweeney S, Gupta R, Taylor G, Calin A (2001) Total hip arthroplasty in ankylosing spondylitis: outcome in 340 patients. J Rheumatol 28:1862–1866
25. Bhan S, Eachempati KK, Malhotra R (2008) Primary cementless total hip arthroplasty for bony ankylosis in patients with ankylosing spondylitis. J Arthroplasty 23:859–866
26. Resnick D, Dwosh IL, Goergen TG, Shapiro RF, D'Ambrosia R (1976) Clinical and radiographic "reankylosis" following hip surgery in ankylosing spondylitis. AJR Am J Roentgenol 126:1181–1188
27. Sundaram NA, Murphy JC (1986) Heterotopic bone formation following total hip arthroplasty in ankylosing spondylitis. Clin Orthop Relat Res 207:223–226
28. Li J, Xu W, Xu L, Liang Z (2009) Hip resurfacing arthroplasty for ankylosing spondylitis. J Arthroplasty 24:1285–1291
29. Burroughs BR, Hallstrom B, Golladay GJ, Hoeffel D, Harris WH (2005) Range of motion and stability in total hip arthroplasty with 28-, 32-, 38-, and 44-mm femoral head sizes. J Arthroplasty 20:11–19
30. Crowninshield RD, Maloney WJ, Wentz DH, Humphrey SM, Blanchard CR (2004) Biomechanics of large femoral heads: what they do and don't do. Clin Orthop Relat Res 429:102–107
31. Wang J, Zhang Y, Zhao L, Li ZH, Shi ZJ (2013) The efficacy and safety of infliximab used in patients with ankylosing spondylitis after unilateral total hip arthroplasty. Hip Int 23:406–410
32. Röder C, Parvizi J, Eggli S, Berry DJ, Müller ME, Busato A (2003) Demographic factors affecting long-term outcome of total hip arthroplasty. Clin Orthop Relat Res 417:62–73