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The Effect of Obesity on the Clinical, Functional and Radiological Outcome of Cementless Total Hip Replacement: A Case-Matched Study With a Minimum 10-Year Follow-Up

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ABSTRACT

1420 primary cementless THRs with a minimum follow-up of 10-years were stratified according to BMI: non-obese (BMI < 30 kg/m^2) and obese (BMI ≥ 30 kg/m^2). Median age at surgery was younger in obese patients ($P < 0.001$). We case-matched 82 THRs in obese patients with 162 THRs in non-obese patients. No difference between groups was found in improvement in HHS ($P = 0.668$), satisfaction with surgery ($P = 0.644$), range of movement, prosthesis orientation, or radiological loosening. The obese cohort was further separated into those with a BMI below and above 35. No difference was found between groups in improvement in HHS, satisfaction with surgery, component orientation, or radiological loosening. There was no difference in the incidence of post-operative complications between obese and non-obese patients. After 10-years, the results of THR are not compromised by obesity.

The World Health Organisation (WHO) has defined obesity as a body mass index (BMI) of ≥30 kg/m^2, with the rise in obesity within the Western World being described as reaching epidemic proportions [1]. Obesity is associated with a number of medical conditions, including coronary artery disease, hypertension, stroke, type 2 diabetes, and osteoarthritis [2]. Obese patients are far more likely to require lower limb joint arthroplasty than non-obese patients [3]. As such, the rise in the numbers of obese individuals has seen a correlation with the number of patients undergoing total hip replacement (THR) [4]. A significant association has been demonstrated between a lower age at THR and an increasing BMI [5]. However, there is a paucity of evidence regarding the long-term results of THR in the obese patient. Perhaps this reflects a reluctance of some surgeons to operate on this cohort — indeed, Charnley [6] recommended that obesity should be a contraindication to THR. Furthermore, some NHS Primary Care Trusts have refused to fund lower limb joint arthroplasty surgery based on a patient's BMI [7]. It has been suggested that performing hip arthroplasty surgery on obese patients may result in a greater incidence of poor component positioning [8,9]. Therefore, it is important to determine the implications of obesity on the clinical, functional and radiological results in THR. We hypothesise that, after 10 years, obese patients have comparable clinical and radiological outcome to non-obese patients. Our aim here was to review the clinical and radiological results of obese patients who underwent cementless THR greater than 10 years ago and compare their data with matched non-obese patients.

Patients and Methods

We examined the results of 1420 consecutive primary cementless THRs which had been performed in 1301 patients between 1997 and 2003. The data from all operations and clinical and radiological examinations were routinely collected prospectively and stored in a database. The clinicians who were responsible for collecting the data (WLW, WKW, BAZ) were blinded to the study. Consent was obtained from all patients for the use of anonymous information for ongoing research projects.

All the procedures took place in a single institution, with the surgery being performed by one of two experienced surgeons (WKW, BAZ). The joint arthroplasty surgery was performed within a high air-flow environment, utilising a posterior approach to the hip joint. All the patients had an ABG2 (Stryker, Mahwah, New Jersey) cementless femoral component implanted, with 1345 also receiving an ABG2 (Stryker) cementless acetabular component. In the

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remaining 75 operations, cementless acetabular components of similar design were utilised. The ABG2 femoral component is an anatomical stem, composed of a $Ti_{12}Mo_6Zr_2Fe$ alloy with a proximal metaphyseal hydroxyapatite (HA) coating. The ABG2 acetabular component is manufactured using a $TiAl_6V_4$ alloy and is a hemispherical design with an HA coating. Of the 1420 hips, bearing combinations included ceramic-on-ceramic, ceramic-on-polyethylene and cobalt chrome-on-polyethylene. Post-operatively, patients had a standardised protocol, that included both mechanical and chemical thromboprophylactic measures, 48 hours of intravenous antibiotics, and mobilisation fully weight bearing as tolerated, under the supervision of physiotherapists. Patients were then followed-up at regular intervals. At each follow-up, patients were asked to complete a questionnaire and underwent a clinical examination performed by one of three senior surgeons (WLW, WKW, BAZ).

The patient's BMI was calculated by dividing their weight in kilogrammes by their height in metres squared. This data was collected at a pre-operative assessment, typically performed between 2 and 4 weeks prior to their joint arthroplasty surgery. It is the policy within our institution not to refuse THR purely on the grounds of a raised BMI. No other pre-operative selection criteria were applied. For the purposes of data analysis, patients were either categorised into obese (BMI $\geq$ 30 kg/m^2) and non-obese (BMI < 30 kg/m^2).

The clinical outcome of the surgery was assessed using the Harris hip score [10] (HHS) a valid and reliable test for determining the outcome of total hip arthroplasty [11]. Known complications specifically relating to the prosthesis (peri-prosthetic fracture, dislocation and infection) were recorded in the database regardless of time after surgery and whether or not the complications were treated at our institution. Our national joint registry was not used to determine the incidence of complications, as only revision rates due to those complications are noted. Infection was defined as deep infection that required surgical intervention. Pulmonary embolism was detected by CT pulmonary angiography. Cerebrovascular accident (CVA) was diagnosed by CT. Cardiovascular complications were only recorded if they occurred within 3 months of the surgery. Other peri-operative data such as superficial wound complications that did not progress to deep infection, transfusion rates, analgesia requirements and lower respiratory tract infections were not recorded.

Patient satisfaction with the surgery was determined using a ten-point visual analogue scale in which zero indicated complete dissatisfaction and ten points total satisfaction. The post-operative range of movement was independently assessed at each clinical follow-up by one of the senior authors (WLW, WKW, BAZ). Radiological assessment of the hip prostheses was performed utilising anteroposterior (AP) pelvic and lateral radiographs. The images were scored by arthroplasty fellows who were blinded to the patient's BMI. None of the arthroplasty fellows were involved in the initial surgery or subsequent clinical follow-up. The radiological assessment of the acetabular component included evaluation for the presence or absence of radiolucent lines and osteolysis according to the three zones described by DeLee and Charnley [12]. The cup inclination (the angle between the face of the component and the transverse axis of the pelvis) was also measured [13]. Each of the seven zones of the femoral component described by Gruen et al [14] was assessed for the presence or absence of radiolucency, osteolysis, femoral cortical hypertrophy, and stress shielding. These areas were also examined for the presence of endosteal weld spots between the implant and surrounding bone [15]. Alignment of the femoral component was classified as either being neutral or non-neutral (varus or valgus). Femoral components were examined for evidence of subsidence by comparing serial radiographs.

A case matched study was performed on all obese patients who had their original primary THR in situ, and had minimum clinical and radiological follow-up of ten years. Patients were matched on the basis of age within 2.5 years, gender, laterality, surgeon, pre-operative diagnosis, and bearing configuration. Given the broad spectrum of co-existing diseases in THR patients, it proved impossible to match patients for co-morbidities. However, pre-operatively, all patients underwent a full anaesthetic assessment to identify and optimise any significant co-morbidities. All case-matched patients had ABG2 femoral and acetabular components implanted. Patients were excluded if any of the required data were incomplete or missing. After application of all inclusion and exclusion criteria we were able to match 82 hip arthroplasties performed in obese patients with those performed in non-obese patients. In all but two cases, we were able to match two non-obese to one obese THR, resulting in a total of 162 hips in the control (non-obese) cohort. A subsequent subgroup analysis of the obese cohort was performed by dividing these patients according to BMI 30–34.9 kg/m^2 (n = 55) and BMI > 35 kg/m^2 (n = 27).

Sample Size

Having identified HHS as the primary indicator of functional outcome, presuming a normal distribution of HHS, a minimum of 73 cases per group was needed to detect a change of 7 points (SD = 15), with a two sided 5% significance level and 80% power [16]. A change of 7 points is the smallest change necessary to suggest a clinically important difference [17].

Statistical Analysis

The results of the analyses were compared using the paired and unpaired two-tailed t-tests. Statistical analysis of the presence or absence of radiographic abnormalities and post-operative complications was performed with Chi-squared tests, with significance set at $P < 0.05$.

Results

Demographics

In the entire series (Table 1), the median age at time of surgery of non-obese patients was 6.8 years older than that of obese patients ($P < 0.001$). The proportion of males to females was 1:1.2 in the non-obese groups and 1:1.1 in the obese group. The demographics of the case-matched series are recorded in Table 2.

Harris Hip Score

In the case matched study, the obese cohort demonstrated statistically significant lower mean pre-operative HHS ($P = 0.006$) (Table 3). Individual components of the pre-operative HHS were not available for analysis, however, post-operatively, the obese patients had significantly worse scores for function ($P < 0.001$) and activities ($P < 0.001$). The total mean HHS was also significantly worse in the obese cohort ($P < 0.001$). However, the obese cohort demonstrated an equivalent mean improvement in HHS (36.5) when compared with the non-obese cohort (35.3, $P = 0.668$).

Table 1
Details for Analysis of the Entire Series.

	All	Non-Obese	Obese	*P* Value
Total Number Implants (%)	1420	1154 (81.3)	266 (18.7)	
Total Number Patients (%)	1301	1060 (81.5)	241 (18.5)	
Gender (%)				
Male	604	489 (81)	115 (19)	
Female	697	571 (81.9)	126 (18.1)	
Median Age in Years (SD)	67.8 (11.6)	69.2 (11.5)	62.4 (10.8)	<0.001
Mean BMI (SD)	26.5 (4.6)	24.8 (2.9)	33.7 (3.2)	

Data analysis: Student T-test.

Table 2
Details for Case-Controlled Study.

	Non-Obese	Obese
Total Number	162	82
Gender		
Male	73	37
Female	89	45
Median Age in Years (SD)	60.4 (8.2)	58.8 (8.7)
Mean Follow-Up Years (SD)	10.9 (1.1)	10.9 (1.1)
Mean BMI (SD)	24.8 (2.8)	34.2 (3.1)

Data analysis: Student T-test.

Range of Movement

Statistical analysis of the independently assessed post-operative range of movement was performed (Table 3). There was no significant difference in flexion ($P = 0.263$), abduction ($P = 0.239$), adduction ($P = 0.331$), external rotation ($P = 0.182$) or internal rotation ($P = 0.07$) between the two cohorts.

Radiological Assessment

With regards to the acetabular component, there was no significant difference in the incidence of radiolucency ($P = 0.155$) or the angle of cup inclination ($P = 0.770$) between obese and non-obese cohorts (Table 4). Further statistical analysis revealed no significant difference in the presence of femoral component radiolucency ($P = 0.983$) cortical hypertrophy ($P = 0.746$), stress shielding ($P = 0.798$), spot welds ($P = 0.646$), or stem malalignment ($P = 0.978$). There was a greater incidence of osteolytic lesions in the non-obese cases ($P = 0.042$). One patient in the obese cohort (BMI 31.2) was noted to have femoral component subsidence of 5 mm. No femoral subsidence was noted in the non-obese group. The number of hip arthroplasties in which positive radiographic findings were visualised is summarised in Table 4.

Complications

Examining occurrences of known complications across the entire series, there were a total of 75 peri-prosthetic fractures (65 non-obese, 10 obese), 28 dislocations (23 non-obese, 5 obese), 9 deep infections (7 non-obese, 2 obese), 16 pulmonary embolisms (15 non-obese, 1 obese), 5 myocardial infarctions (all in non-obese cohort) and 1 CVA (a non-obese patient) (Tables 5 and 6). Statistical analysis of these figures revealed no significant difference between obese and non-obese patients in the incidence of peri-prosthetic fracture ($P = 0.218$), dislocation ($P = 0.901$), deep sepsis ($P = 0.788$), pulmonary embolism ($P = 0.198$), myocardial infarction ($P = 0.282$) or CVA ($P = 0.631$).

Table 3
Mean Clinical Results (SD) in the Case-Matched Series.

	Non-Obese (n = 162)	Obese (n = 82)	*P*-Value
Pre-Op Harris Hip Score	58.7 (15.8)	52.4 (16.8)	0.006
Post-Op Harris Hip Score			
Total	94.1 (7.1)	88.9 (12.8)	0.001
Pain	42.1 (5.4)	40.1 (8.5)	0.044
Function	31.6 (3.8)	30.0 (4.2)	0.001
Activities	12.1 (2.4)	11.0 (2.6)	0.001
Range of Movement	8.1 (1.3)	8.1 (1.0)	0.822
Improvement in Total HHS	35.3 (17.0)	36.5 (18.8)	0.668
Hip Flexion	111.2 (19.2)	108.3 (15.5)	0.263
Abduction	29.2 (8.0)	27.9 (6.5)	0.239
Adduction	23.2 (5.6)	22.5 (5.1)	0.331
External Rotation	24.5 (6.6)	25.6 (6.6)	0.182
Internal Rotation	13.1 (9.4)	10.9 (8.3)	0.07
Satisfaction Score/10	9.46 (1.3)	9.38 (0.9)	0.644

Data analysis: Student T-test.

Table 4
Radiological Results in the Case-Matched Series.

	Non-Obese (n = 162)	Obese (n = 82)	*P*-Value
Acetabular Component			
Number of Hips Identified With:			
Radiolucency (%)	4 (2.5)	5 (6.1)	0.155
Osteolysis (%)	12 (7.4)	1 (1.2)	0.042
Mean Cup Inclination (SD)	49.7 (5.8)	49.4 (6.5)	0.770
Femoral Component			
Number of Hips Identified With:			
Radiolucency (%)	8 (4.9)	4 (4.9)	0.983
Cortical Hypertrophy (%)	18 (11.11)	8 (9.8)	0.746
Stress Shielding (%)	41 (25.3)	22 (26.8)	0.798
Spot Welds (%)	24 (14.8)	14 (17.1)	0.646
Subsidence (%)	0	1 (1.2)	0.159
Non-Neutral Alignment (%)	14 (8.6)	7 (8.5)	0.978

Data analysis: Chi-square test for incidences. Student T-test for cup inclination.

Subgroup Analysis

The obese cases with complete clinical and radiological follow-up (n = 82) were subdivided into BMI 30–34.9 (n = 55) and BMI > 35 kg/m^2 (n = 27), and the results compared with their respective case-matches (Tables 7 and 8). The only statistically significant results were a difference in the pre-operative ($P = 0.006$) and post-operative ($P < 0.001$) HHS between the BMI 30–34.9 kg/m^2 and their matched patients. All other results in both subgroups failed to demonstrate a significant result between non-obese and obese patients.

Discussion

Obesity has been associated with the development of osteoarthritis of the hip [18], and consequently a strong correlation exists between BMI and the need for lower limb joint arthroplasty [3]. However, considerable debate exists as to the effect of obesity on the outcome of total hip arthroplasty. Whilst some studies support the use of arthroplasty to treat osteoarthritis in the obese [8,19,20], others report higher rates of complications [21,22] and even recommend weight loss prior to joint arthroplasty [23]. The functional benefit of total hip arthroplasty in the obese has also been questioned [24], perhaps suggesting that such procedures should be reserved for non-obese patients.

We were able to examine the functional and radiological outcomes in obese patients with a minimum follow-up of 10 years, by matching them with non-obese patients, thus reducing the potential for confounding factors. The results of our study show that obese patients have significantly inferior pre-operative and post-operative HHS when compared with non-obese patients. However, there was no difference between the cohorts when comparing the relative improvement in HHS achieved through joint arthroplasty. We believe

Table 5
Post-Operative Complications in Entire Series.

	Non-Obese (n = 1154)	Obese (n = 266)	*P*-Value
Fracture (%)	65 (5.6)	10 (3.8)	0.218
Dislocation (%)	23 (2.0)	5 (1.9)	0.901
Infection (%)	7 (0.6)	2 (0.8)	0.788
Pulmonary Embolism (%)	15 (1.3)	1 (0.4)	0.198
Myocardial Infarct (%)	5 (0.4)	0	0.282
Cerebrovascular Accident (%)	1 (0.09)	0	0.631

Data analysis: Chi-square test.

Table 6
Complications in the Entire Obese Series According to BMI.

	30–34.9 (n = 192)	BMI 35–39.9 (n = 57)	>40 (n = 17)	Total (n = 266)
Fracture Femur (%)	7 (3.7)	3 (5.2)	0	10 (3.8)
Dislocation (%)	4 (2.1)	1 (1.8)	0	5 (1.9)
Infection (%)	1 (0.5)	0	1 (5.9)	2 (0.8)
P.E (%)	1 (0.5)	0	0	1 (0.4)

this improvement to be more meaningful than actual post-operative HHS, a theory reinforced by the fact that overall satisfaction with surgery was nearly identical in obese and non-obese patients. This suggests that the functional benefit of surgery to an individual is unrelated to their pre-operative BMI.

A comprehensive radiological appraisal of the acetabular and femoral components of the hip arthroplasties revealed no evidence to suggest that obese patients demonstrate increased stem subsidence or earlier radiological signs of loosening. Whilst there is evidence that obese patients are at increased risk of component malpositioning [9,25,26], analysis of our series found no statistical difference in cup inclination between the two cohorts, supporting the argument that BMI does not necessarily influence the accuracy of cup positioning in total hip arthroplasty [27,28].

The strengths of our study are that it was a case-matched study performed on patients on whom surgery had been performed over ten years ago with 2:1 case match, the same femoral and acetabular components were used in all cases, and data were collected prospectively pre-operatively and ten years post-operatively by individuals who were blinded to the study.

Our study has a number of limitations. Whilst we have used the WHO definition of obesity as our yard stick, this cut off point could be considered too low. We have attempted to address this by performing a subgroup analysis. However, the numbers within our subgroups are small, and hence statistical analysis here is liable to a type 2 error. In addition, with only five morbidly obese patients (BMI > 40 kg/m^2) in the case matched cohort, we did not analyse this subgroup independently. Further limitations of the study are that the surgeon, bearing combination demographics, and pre-operative diagnosis were not standardised, although we have reduced these confounding variables by performing a matched study. Whilst co-existing diseases may affect THR outcome, patients were not matched for co-morbidities. However, all patients were graded between 1 and 3 on American Society of Anaesthesiologists' (ASA) classification. Radiological examinations were performed by different observers using predetermined criteria, however, intra-observer variability tests were not performed. Given the low incidence of complications within the case-matched series, we analysed the incidence of complications across the series as a whole. However, there were insufficient numbers of complications that occurred within the higher BMI cases to draw a conclusion on the effect of significant obesity on complication rates. Our national joint registry does not record individual occurrences of complications, and therefore determination of complication rates is reliant upon local audit and accurate feedback from other institutions. Ours is a single institution study, and therefore, these results may reflect the experience of the operating surgeons. Whilst it could be viewed that a failure to not routinely measure the post-operative BMI is another weakness to our study, there is good evidence to suggest that weight loss after arthroplasty surgery is unlikely, and indeed BMI may even increase [29–33]. Therefore, we believe it is not unreasonable to make the assumption to make that the majority of patients will not significantly change their BMI category.

In response to our initial hypothesis, amongst our cohort of patients, 10 years after implantation, obese individuals gain as much clinical improvement from cementless total hip arthroplasty as non-obese patients, with no evidence of a higher rate of associated significant complications. Obese patients can therefore be counselled accordingly. Furthermore, there is little to suggest that obese patients demonstrate premature radiological evidence of prosthetic loosening when compared with non-obese patients. Importantly, our results found no indication that severely obese patients (BMI > 35 kg/m^2) in particular have inferior long term results after total hip arthroplasty. Nevertheless, it should be considered that the results of this study are specific to our institution and may not reflect the results of the orthopaedic community as a whole. Consequently, we believe that, withholding total hip arthroplasty surgery based purely on BMI is unjustified and that delaying surgery until such time that the patient loses weight is unreasonable.

Table 7
Clinical and Radiological Results of Case-Matched Subgroup Analysis (Non-Obese vs BMI 30–34.9 kg/m^2).

	Non-Obese (n = 109)	Obese (BMI 30–34.9) (n = 55)	*P*-Value
Mean BMI (SD)	24.8 (2.8)	32.4 (1.5)	
Mean Pre-Op HHS (SD)	58.9 (16.5)	51.3 (15.6)	0.006
Mean Post-Op HHS (SD)	94.2 (6.8)	88.4 (14.1)	<0.001
Improvement in Total HHS (SD)	35.3 (2.8)	37.1 (19.1)	0.797
Satisfaction Score/10 (SD)	9.6 (1.0)	9.4 (0.9)	0.124
Acetabular Component			
Number of Hips Identified With:			
Radiolucency (%)	2 (1.8)	3 (5.5)	0.203
Osteolysis (%)	8 (7.3)	2 (3.6)	0.349
Mean Cup Inclination (SD)	50.3 (5.6)	50.2 (6.3)	0.931
Femoral Component			
Number of Hips Identified with:			
Radiolucency (%)	5 (4.6)	3 (5.5)	0.808
Cortical Hypertrophy (%)	13 (11.9)	5 (9.1)	0.583
Stress Shielding (%)	27 (24.8)	15 (27.3)	0.729
Spot Welds (%)	16 (14.7)	11 (20.0)	0.386
Subsidence (%)	0	1 (1.8)	0.162
Non-Neutral Alignment (%)	12 (11.0)	6 (10.9)	0.985

Data analysis: Chi-square test for radiological incidences. Student T-test for HHS, satisfaction score and cup inclination.

Table 8
Clinical and Radiological Results of Case-Matched Subgroup Analysis (Non-Obese vs BMI > 35 kg/m^2).

	Non-Obese (n = 53)	Obese (BMI > 35) (n = 27)	*P*-Value
Mean BMI (SD)	25.0 (2.8)	37.5 (2.9)	
Mean Pre-Op HHS (SD)	59.0 (13.6)	58.6 (18.9)	0.276
Mean Post-Op HHS (SD)	93.0 (7.0)	86.4 (9.1)	0.210
Improvement in Total HHS (SD)	33.9 (14.9)	27.8 (18.4)	0.650
Mean Satisfaction Score/10 (SD)	9.3 (1.77)	9.5 (0.94)	0.673
Acetabular Component			
Number of Hips Identified With:			
Radiolucency (%)	2 (3.8)	2	0.481
Osteolysis (%)	4 (7.6)	1	0.502
Mean Cup Inclination (SD)	48.5 (6.1)	48.4 (6.8)	0.700
Femoral Component			
Number of Hips Identified With:			
Radiolucency (%)	3 (5.7)	1 (3.7)	0.704
Cortical Hypertrophy (%)	5 (9.4)	3 (11.1)	0.813
Stress Shielding (%)	14 (26.4)	7 (25.9)	0.963
Spot Welds (%)	8 (15.1)	3 (11.1)	0.623
Subsidence (%)	0	0	
Non-Neutral Alignment (%)	2 (3.8)	1 (3.7)	0.988

Data analysis: Chi-square test for radiological incidences. Student T-test for HHS, satisfaction score and cup inclination.

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References

1. Obesity: preventing and managing the global epidemic, technical report series 894. Part 1: the problem of overweight and obesity: defining the problem. World Health Organ 2000:6.
2. What are the health risks of overweight and obesity? U.S department of Health and Human Services: National Heart, Lung and Blood Institute. http://www.nhlbi.nih.gov/health/health-topics/topics/obe/risks.html.
3. Bourne R, Mukhi S, Zhu N, et al. Role of obesity on the risk for total hip or knee arthroplasty. Clin Orthop Relat Res 2007;465:185.
4. Wang Y, Bendoun MA. The obesity epidemic in the United States: gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and met-regression analysis. Epidemiol Rev 2007;29:6.
5. Cheangulani M, Kalairajah Y, Peel T, et al. The relationship between obesity and the age at which hip and knee replacement is undertaken. J Bone Joint Surg (Br) 2008;90-B:360.
6. Charnley. Long term results of low-friction arthroplasty. Hip 1982:42.
7. http://www.bbc.co.uk/news/uk-england-beds-bucks-herts-16525908.
8. Tsukada S, Wakui M. Decreased accuracy of acetabular cup placement for imageless navigation in obese patients. J Orthop Sci 2010;15(6):758.
9. Callanan MC, Jarrett B, Bragdon CR, et al. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. Clin Orthop Relat Res 2011;469(2):319.
10. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures; treatment by mold arthroplasty. J Bone Joint Surg Am 1969;51-A:737.
11. Söderman P, Malchau H. Is the Harris hip score system useful to study the outcome of total hip replacement? Clin Orthop Relat Res 2001;384:189.
12. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop 1976;121:20.
13. Lewinneck GE, Lewis JL, Tarr R, et al. Dislocations after total hip arthroplasties. J Bone Joint Surg Am 1978;60-A:217.
14. 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.
15. Engh CA, Massin P, Suthers KE. Roentgenographic assessment of the biologic fixation of porous surfaced femoral components. Clin Orthop 1990;257:107.
16. Achten J, Parsons NR, Edlin RP, et al. A randomised controlled trial of total hip arthroplasty versus resurfacing arthroplasty in the treatment of young patients with arthritis of the hip joint. BMC Musculoskelet Disord 2010;11:8.
17. Beaton DE. Simple as possible? Or too simple? Possible limits to the universality of the one half standard deviation. Med Care 2003;41(5):593.
18. Lievense AM, Bierma-Zeinstra SM, Verhagen AP, et al. Influence of obesity on the development of osteoarthritis of the hip: a systematic review. Rheumatology (Oxford) 2002;41(10):1155.
19. McMalden RW, Charron KD, MacDonald SJ, et al. Does morbid obesity affect the outcome of total hip replacement? J Bone Joint Surg (Br) 2011;93-B:321.
20. McLaughlin JR, Lee KR. The outcome of total hip replacement in obese and non-obese patients at 10- to 18-years. J Bone Joint Surg (Br) 2006;88:B1286–.
21. Sadr Azodi O, Adami J, Lindstrom D, et al. High body mass index is associated with increased risk of implant dislocation following primary total hip replacement: 2,106 patients followed up for 8 years. Acta Orthop 2008;79:141.
22. Dowsey MM, Choong PF. Obesity is a major risk factor for prosthetic infection after primary hip arthroplasty. Clin Orthop 2008;466:153.
23. Chee YK, Teoh KH, Sabnis BM, et al. Total hip replacement in morbidly obese patients with osteoarthritis. J Bone Joint Surg (Br) 2010;92-B:1066.
24. McClung CD, Zahiri CA, Higa JK, et al. Relationship between body mass index and activity in hip or knee arthroplasty patients. J Orthop Res 2000;18(1):35.
25. Elson LC, Barr CJ, Chandran SE, et al. Are morbidly obese patients undergoing total hip arthroplasty at an increased risk for component malpositioning? J Arthroplasty 2013;28(8 Suppl.):41.
26. McBride A, Flynn J, Miller G, et al. Body mass index and acetabular component position in total hip arthroplasty. ANZ J Surg 2013;83(3):171.
27. Todkar M. Obesity does not necessarily affect the accuracy of acetabular cup implantation in total hip replacement. Acta Orthop Belg 2008;74:206.
28. Pirard E, De Lint JA. Anteversion of the acetabular component in obese patients. Hip Int 2007;17(2):99.
29. Middleton FR, Boardman DR. Total hip arthroplasty does not aid weight loss. Ann R Coll Surg Engl 2007;89:288.
30. Woodruff MJ, Stone MH. Comparison of weight changes after total hip or knee arthroplasty. J Arthroplasty 2001;16:22.
31. Donovan J, Dingwall I, McChesney S. Weight change 1 year following total knee or hip arthroplasty. ANZ J Surg 2006;76(4):222.
32. Abu-Rajab RB, Findlay H, Young D, et al. Weight changes following lower limb arthroplasty: a prospective observational study. Scott Med J 2009;54(1):26.
33. Jain SA, Roach RT, Travlos J. Changes in body mass index following primary elective total hip arthroplasty. Correlation with outcome at 2 years. Acta Orthop Belg 2003;69(5):421.