Outcome of revision hip arthroplasty in patients with a previous total hip replacement for developmental dysplasia of the hip

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Our aim was to determine if the height of the cup, lateralisation or the abduction angle correlated with functional outcome or survivorship in revision total hip replacement in patients with a previous diagnosis of developmental dysplasia of the hip. A retrospective investigation of 51 patients (63 hips) who had undergone revision total hip replacement was performed. The mean duration of follow-up was 119 months. Forty-one patients (52 hips) were available for both determination of functional outcome and survivorship analysis. Ten patients (11 hips) were only available for survivorship analysis.

The height of the cup was found to have a statistically significant correlation with functional outcome and a high hip centre correlated with a worse outcome score. Patients with a hip centre of less than 3.5 cm above the anatomical level had a statistically better survivorship of the cup than those with centres higher than this. Restoration of the height of the centre of the hip to as near the anatomical position as possible improved functional outcome and survivorship of the cup.

Revision total hip replacement (THR) in patients with a previous diagnosis of developmental dysplasia of the hip (DDH) can be a challenging and technically demanding procedure. Two major concerns are deficient acetabular bone stock and the position of the acetabular implant, particularly if the centre of the hip has not been restored during the primary procedure. Various techniques have been reported for acetabular reconstruction in patients with DDH. One of the most common is restoration of the acetabulum to almost its correct anatomical level, in combination with a shelf autograft. However, some advocate the use of a high hip centre in order to take advantage of remaining bone stock and to avoid the use of a structural graft. This technique does not contribute to the correction of limb-length discrepancy, does not provide good bone stock for revision surgery and is associated with early acetabular loosening and a higher rate of dislocation because of ischial impingement. Placement of the cup at an anatomical level helps to restore leg length but may require the use of a structural bone graft to the shallow acetabulum and deficient superolateral roof.

Our aim was to determine if the height of the cup, lateralisation or abduction angle correlated with the functional outcome or survivorship in revision THR in patients with previous DDH.

Patients and Methods
From our revision database which had been established in 1984, we identified 75 consecutive patients (87 hips) who had undergone revision THR after having had a previous THR for DDH. To be included in this study patients had to live in Canada, have sufficient mental acuity to answer the functional outcome questionnaires, and to have a minimum follow-up of three years. We found that 57 patients (69 hips) met these criteria. Two had died from unrelated causes more than 13 years after revision and their radiographs were not available. They were therefore excluded from the study. Four were lost to follow-up less than three years after revision arthroplasty. The remaining study group consisted therefore of 44 women and seven men with a mean age of 54.4 years (30 to 77) at the time of their revision arthroplasty. The mean length of follow-up was 119 months (36 to 238). Of the 51 patients (63 hips), 41 (52 hips) were available for both functional outcome assessment and survivorship analysis. The remaining ten (11 hips) were available for survivorship analysis only either because they refused to complete their questionnaires (three patients, three hips) or because they had undergone a re-revision arthroplasty of their hip within the last three years (seven patients, eight hips; Table I).

Data were obtained from pre-operative, intra-operative and post-operative records and
radiographs including: 1) pre-operative diagnosis and symptoms; 2) intra-operative documentation of bone loss; 3) the use of morcelised bone graft, defined as fragments of cancellous bone ranging from 5 to 10 mm in diameter; 4) the use of a minor column graft (also termed a shelf graft) which supported less than 50% of the cup; 5) the use of a major column allograft, defined as an acetabular allograft which involved at least 50% of the acetabulum; 6) the use of rings or cages, and 7) post-operative complications.6

The patients had undergone a mean of 2.33 previous operations (1 to 8) on their revised hip. At the initial THR, a cemented cup had been used in 43 hips and an uncemented cup with a shelf autograft in 20. Bone loss was defined intra-operatively according to the classification of Gross.7,8 Nineteen hips had a type-I contained defect in the acetabulum. Thirteen of them were managed with morcelised allograft and an uncemented cup, while the remaining six had morcelised allograft and a roof ring with a cemented cup. Twenty-eight hips had a type-IIA uncontained defect and were managed by a minor column allograft and an uncemented cup. Sixteen hips had a type-IIB uncontained defect and were treated by a major column allograft and an antiprotrusio cage with a cemented cup. Thirty patients (35 hips) underwent revision of their femoral component as well as the acetabulum. The femoral component was revised with a cemented stem in 20 hips. Eight required a proximal femoral allograft and another seven cortical strut allografts in addition to an uncemented stem. In 28 hips, the femoral component was found to be soundly fixed and was not revised.

Post-operative records were reviewed for complications and post-operative anteroposterior (AP) radiographs were assessed for the position of the cup and orientation. The horizontal and vertical distances from the centre of the hip to the teardrop and the angle of acetabular cover were recorded. Measurements were referenced from the interteardrop line and the angle of the cup in the coronal plane as described by Yoder et al9 (Fig. 1). Radiographs obtained at the most recent follow-up were used to determine whether there was loosening of the cup using the following classification system loosening: 1) possible loosening, a radiolucent line between the cup and pelvis in two zones; 2) probable loosening, a radiolucent line in all three zones but with no migration and; 3) definite loosening with migration of the cup.10,11

Migration of the cup was defined as > 4 mm or 4° of change in position of the cup.5,9,12 All measurements were made with the computerised Picture Archiving and Communications Systems imaging workstation (Merge Efilm Technology Inc, Milwaukee, Wisconsin). The patients were divided into two groups according to height of the cup. Group 1 included patients with a height of < 35 mm proximal to the interteardrop line and group 2 those with a height of ≥ 35 mm proximal to the interteardrop line, so the so-called high hip centre.1,2,13 Both groups were closely matched for the number of morcelised or structural grafts used (Table II).

As suggested in the literature, it is preferable to use both a disease-specific and a generic questionnaire to measure func-
tional outcome.\textsuperscript{14} Therefore the Western Ontario and McMaster Universities osteoarthritis (WOMAC) index and the Harris hip score were used as disease-specific measurements and the short form 36 (SF-36) as the generic health score.\textsuperscript{12,13-17} Thirty-three patients (42 hips) completed these functional assessments at their most recent follow-up visits. Four patients underwent a revision procedure of only the femoral component for reasons unrelated to the acetabulum (two for an united proximal femoral allograft, one for a periprosthetic fracture, and one for aseptic loosening of the femoral component). For these patients, we measured the functional outcome after their femoral revision. Because we were interested in the performance of the acetabular component, functional measurements at that time were considered to be valid. For survivorship analysis, failure of the acetabular component was defined as either revision of the acetabular component or being placed on a waiting list for revision of the cup.

**Statistical analysis.** This was performed using SPSS software (Version 10; SPSS Inc, Chicago, Illinois). The height of the cup, lateralisation, and angle were identified as possible independent variables which might affect the functional outcome. In order to determine if there was a relationship between these variables and functional outcome, linear regression analysis was performed. Student’s $t$-test was used to compare the means. Kaplan-Meier survivorship curves were obtained and compared for both groups. Statistical significance of differences in survivorship were tested using the log rank method with $p < 0.05$ being regarded as significant for all analyses.

**Results**

At the time of their most recent follow-up, 41 patients (52 hips) were available for functional outcome scores. The mean Harris hip score was 78 (50 to 97) with 24 hips having good and excellent results, 18 fair and ten poor.

**Clinical.** Linear regression analysis revealed a significant correlation between the mean height of the cup 37 mm (17 to 76) and functional outcome ($p < 0.003$). A lower position of the cup correlated with a better functional outcome score in the WOMAC, Harris hip and SF-36 scores. The mean angle of the cup was 39˚ (30˚ to 48˚) and mean horizontal distance 39 mm (28 to 56) were not found to be variables which affected the functional outcome for the scores which we used. The mean Harris hip score for group 1 was 83 (69 to 97). In this group, 19 hips had good to excellent scores, nine fair and one poor. The mean Harris hip score for group 2 was 70 (50 to 85) with five hips having good scores, ten fair and eight poor ($p < 0.001$).

The mean WOMAC score for all patients was 70 (36 to 94). Linear regression analysis revealed a significant correlation between the height of the cup and the functional outcome ($p < 0.011$). The mean WOMAC score for group 1 was 77 (60 to 94) and for group 2, 62 (36 to 84) ($p < 0.001$).

The SF-36 general health score is composed of eight sub-scales summarised into two main scores, the physical and mental component scores. The mean physical component score for all patients was 43 (30 to 55) and the mean mental component score was 53 (26 to 67). Linear regression analysis revealed a significant correlation between the cup height and the physical component score ($p < 0.017$) but not with the mental component score ($p = 0.074$). The mean physical component score for group 1 was 45 (30 to 55) and the mean mental component score 55 (40 to 64). The mean physical component score for group 2 was 40 (30 to 54) and the mean mental component score 51 (29 to 67; $p = 0.029$ and 0.169, respectively). The mean leg-length inequality was 1.5 cm (0 to 6) for group 1 and 1.3 cm (0 to 3.5) for group 2. This showed no significant difference ($p = 0.33$).

**Radiological.** Radiological analysis of the 55 hips which did not require a re-revision revealed six with asymptomatic possible loosening, two in group 1 (6.7%) and four in group 2 (16%). Three had probable loosening of the cup, one in group 1 (3.3%) and two in group 2 (8%). One patient complained of slight pain but did not receive a re-revision procedure. Five patients had symptomatic, definite loosening of the cup and were awaiting a re-revision arthroplasty, one in group 1 (3.3%) and four in group 2 (16%). Three had probable loosening of the cup, one in group 1 and two in group 2 (8%). One patient had a problem with wound healing. One patient in group 1 had a dislocation three weeks after operation, was treated by closed reduction, and did not have further dislocations. One patient from each group had a post-operative palsy of the sciatic nerve. The patient in group 1 recovered almost completely and the patient in group 2 remained with a complete foot-drop.

**Survivorship analysis.** Fifty-one patients (63 hips) were available for survivorship analysis. Eight patients, two in group 1 (6.2%) and six in group 2 (19%), had undergone a re-revision arthroplasty during the period of study. Three of those from group 2 (9.7%) had recurrent dislocation while the other five required a re-revision because of aseptic loosening of the cup. Five patients, one in group 1 (3.1%) and four in group 2 (12.9%), are awaiting re-revision for aseptic loosening of the cup. Survivorship analysis using the Kaplan-Meier curves revealed a better survivorship for group 1 ($p = 0.0415$). The survival rate of the cup at 15 years was 94.1% (95% confidence interval (CI) 88 to 99) for group 1 and 82.3% (95% CI 74 to 90) for group 2. That at 15 years was 86% (95% CI 77 to 95) for group 1 and 64% (95% CI 53 to 75) for group 2 (Fig. 2).

**Discussion**

There is a paucity of information about revision arthroplasty of the hip in patients with DDH and very few reports correlate functional outcome with position of the cup in

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**Table II. The type of graft used in each group**

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Morcellised graft</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Minor column graft</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Major column graft</td>
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<tr>
<td>Total</td>
<td>32</td>
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revision THR. To our knowledge there are none which compare the functional outcome and survivorship of a prosthesis in relation to the height of the hip centre.

Revision of the acetabular component of a THR can be a challenging procedure because of deficient bone stock, especially in patients with a previous diagnosis of DDH. The pattern of bone loss associated with DDH is a reduced AP diameter combined with poor superior support. This loss is further increased by surgical bone loss at the primary operation, migration of the cup and particle-induced osteolysis. Anatomical placement of the acetabular component should be the goal in revision THR. However, it is sometimes impossible to achieve adequate contact between the host bone and the implant because of severe and progressive bone destruction after the primary procedure. This pattern of bone loss can be managed by filling the defect with cement, by the use of allograft bone, by proximal placement of the cup, or by using special implants such as oblong, pedestal and jumbo cups, or antiprotrusio rings.18-22

Various studies have investigated the biomechanics of the hip in relation to changes in the centre of rotation of the hip. Johnston, Brand and Crowninshield23 used a mathematical model to analyse joint contact forces and found that the most important factor influencing the load on the hip was the location of the hip centre. The best position for reduction of load was achieved by placing the cup medially, inferiorly and as anteriorly as possible. The greatest loads were found when the centre of the hip was placed superiorly, laterally and somewhat posteriorly. Delp et al24 used a three-dimensional computerised model of the hip and surrounding musculature in order to calculate the moment arms, forces and moments generated when the hip abductors were activated. A total hip prosthesis was implanted and three positions of the hip centre were analysed; superolateral, superior and superomedial. Their study demonstrated that superolateral placement of the centre of the hip decreased the abductor moment arm significantly and could not be restored by increasing neck length. Because superolateral placement of the centre of the hip increased the distance between it and the body-weight force vector, the ratio of the body-weight moment arm to the abductor moment arm increased. This resulted in an increased joint reaction force. Superior placement of the centre of the hip mildly decreased the abductor moment arm which could almost be restored by increasing neck length. They concluded that superior positioning of the centre of the hip without lateral displacement did not adversely affect the biomechanics of a replaced hip when femoral neck length was increased appropriately.

Callaghan et al25 reported the results of 146 hip revisions between two and five years after surgery and found that loosening of the acetabular component was attributed to high placement of the cup in 41%. Most of the loose components were also laterally displaced. Yoder et al26 determined the horizontal distance and height of the cup in 116 THRs and found that the location of the centre of the hip was significant for femoral loosening, higher loosening rates being apparent when the cup had been placed superiorly or superolaterally. However, although they did not demonstrate significance for acetabular loosening, they did show a trend, with decreased loosening of the cup when it was placed in a more anatomical position. Russotti and Harris27 reported a long-term follow-up 11 years after cemented THR with proximal placement of the cup in 37 patients. Of these, 31 had excellent or good results while six cups (16%) were loose. They concluded that isolated proximal placement of the cup without lateralisation did not adversely affect the functional outcome or the incidence of loosening of the cup. By contrast, Pagano et al28 assessed the effect of the position on the long-term durability of both the femoral and acetabular components in 117 patients (145 hips) with DDH who had undergone a cemented THR. They found that proximal placement of the acetabulum, even without lateral displacement led to increased rates of loosening of both components.

In our study we have examined the long-term follow-up of revision THR in a group of patients with DDH. We found a significant correlation between the height of the cup and functional outcome, with better outcome and survivorship when the cup was < 35 mm proximal to the interteardrop line. The re-revision rate of the cup was 15% (eight hips) overall, with six from the high hip centre group (19%) and only two from the low hip centre group (6.2%). Both groups were closely matched for the number of morcellised or structural grafts (Table II).

Lateral placement of the hip centre was not found to be a significant variable which affected functional outcome and survivorship. We assume that the main cause for not finding significance in lateral displacement of the cup was that 57 hips were within the normal range (30 to 49 mm)
and the other six, two in group 1 and four in group 2, were only mildly laterally displaced (50 to 56 mm). The angle of the cup was found not to be significant for either outcome or survivorship, probably because all the angles were within normal limits (30° to 48°).

The use of shelf autografts fashioned from the resected head of the femur was reported by Mulroy and Harris11 and Gerber and Harris28 with good early results after a mean follow-up of 7.1 years. They found, however, that the rate of failure increased after follow-up for 11.8 years because the graft progressively resorbed. Because of the high rate of failure with shelf autografts, Russotti and Harris advocated placing the cup proximally.

Morsi et al1 reported the use of shelf grafts of the femoral head with a rate of success of 90% at a mean follow-up of 8.1 years. Subsequently, Jaroszynski et al4 reported their results with shelf allografts in 67 dysplastic hips after a mean follow-up of 119 months. The overall survivorship at 14 years was 78% for the cups. Seven hips (10%) showed resorption of more than one-third of their graft. Six of these showed moderate resorption of between one-third and one-half of the graft. Three were revised with no need for a further structural graft. One hip showed severe resorption of the graft (more than half) and required revision of the cup with insertion of a new graft. Bobak et al27 reported their experience with a shelf graft of the femoral head in 41 patients with DDH. They reported that all grafts had united at a mean follow-up of 11 years and no revisions were needed. Hasegawa et al28 showed, in a series of 25 patients, that the grafted femoral head had incorporated seven months after surgery and had remodelled completely by 18 months, although the grafted bone had reduced in size significantly. Bal, Maurer and Harris29 showed that a healed bulk graft which had been used at the primary operation provided valuable bone stock for the support of an acetabular component during revision THR.

Based upon our clinical experience and a review of the literature, we advocate positioning the cup as close as possible to the anatomical position. During primary procedures for DDH, we use a shelf autograft and a morcelised flying buttress if less than 70% of host bone contact is made with the cup.4 Upon revision of these implants, the shelf grafts typically are well incorporated and the flying buttress has remodelled. When revising a cup in a hip which has received a previous shelf autograft, an anatomical or nearly anatomical height of the cup can often be achieved and structural grafts are seldom necessary.4,20 These results strongly suggest that restoration of the centre of the hip as close as possible to its normal height above the teardrop improves functional outcome and survivorship of the cup.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


