Three-dimensional custom-designed cementless femoral stem for osteoarthritis secondary to congenital dislocation of the hip

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A clinical and radiological study was conducted on 97 total hip replacements performed for congenital hip dislocation in 79 patients between 1989 and 1998 using a three-dimensional custom-made cementless stem. The mean age at operation was 48 years (17 to 72) and the mean follow-up was for 123 months (83 to 182).

According to the Crowe classification, there were 37 class I, 28 class II, 13 class III and 19 class IV hips. The mean leg lengthening was 25 mm (5 to 58), the mean pre-operative femoral anteversion was 38.6˚ (2˚ to 86˚) and the mean correction in the prosthetic neck was -23.6˚ (-71˚ to 13˚). The mean Harris hip score improved from 58 (15 to 84) to 93 (40 to 100) points. A revision was required in six hips (6.2%). The overall survival rate was 89.5% (95% confidence interval 89.2 to 89.8) at 13 years when two hips were at risk.

This custom-made cementless femoral component, which can be accommodated in the abnormal proximal femur and will correct the anteversion and frontal offset, provided good results without recourse to proximal femoral corrective osteotomy.

Patients and Methods
Between 1989 and 1998, 116 consecutive primary THRs were performed in 97 patients with OA following congenital dislocation of the hip. Two patients died of causes unrelated to the procedure before a minimum follow-up of five years, and 16 were lost to follow-up, leaving 79 patients (97 hips) at a mean follow-up of 123 months (83 to 182). There were 74 females and five males, with a mean age at the time of operation of 48 years (17 to 72), a mean weight of 64 kg (42 to 118) and a mean height of 162 cm (150 to 185). Treatment was required on 50 left hips and 47 right hips. The degree of subluxation or dislocation generally matches the difficulty of restoration of the centre of rotation at the level of the true acetabulum, which is required to restore the adductor lever arm and joint kinematics.

However, the variability reported for the canal flare index and proximal femoral anteversion in a 3D anatomical study showed that the femoral prosthesis could not be selected based on the severity of subluxation.

A number of different approaches have been proposed, including the use of miniaturised cemented implants, a subtrochanteric osteotomy to accommodate a standard stem, the use of modular stems or cemented custom-designed femoral components. We have evaluated the clinical and radiological results of custom-made cementless femoral components in THR performed for OA following developmental dysplasia of the hip.

Total hip replacement (THR) in adults with osteoarthritis (OA) resulting from congenital dislocation of the hip is known to be technically demanding. An abnormal location for the centre of rotation of the hip, proximal femoral deformity, soft-tissue contracture, abnormal muscle development and poor bone stock may lead to specific intra-operative difficulties and a consequentially higher complication rate.

Attention is commonly drawn to the acetabular problems but the proximal femoral anatomy may lead to some difficulties with conventional designs of stem. Comparisons of the three-dimensional (3D) anatomy of the hip in developmental dysplasia and primary OA highlight important differences both for the intramedullary femoral anatomy and the extramedullary parameters for each grade of dislocation. The severity of the dislocation generally matches the difficulty of restoration of the centre of rotation at the level of the true acetabulum, which is required to restore the abductor lever arm and joint kinematics.

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in childhood. Based on an estimation of the lengthening needed to restore Shenton’s line, a mean correction of 2.5 cm (0.5 to 5.8) was required. However, complete correction was not necessarily the objective, as consideration was given to the presence of a fixed spinal deformity, fixed pelvic obliquity, fixed flexion of the knee and for ankle and foot equinus or a contralateral THR. The degree of correction was assessed clinically pre-operatively and sometimes with the addition of full-length lateral views of the lower limbs.

Prosthesis design. We have previously described the radiological and CT protocol for the design of a prosthesis, including an anteroposterior (AP) view of the pelvis, AP and lateral views of both hips, and full-length AP views of both legs. Each patient had a CT analysis with slices every 5 mm from the acetabulum to the lesser trochanter and every 10 mm from the lesser trochanter to the ischium, for the analysis of the intramedullary femoral anatomy. Three horizontal slices of the foot in the axis of the second metatarsal, the knee at the level of the epicondylar axis, and 10 mm above the top of the lesser trochanter were necessary for assessment of femoral neck anteversion. One more slice was required to measure the AP acetabular diameter. From these radiological images femoral anteversion was measured, the correction required to restore the leg length was calculated and the angle required for the neck-shaft angle of the femoral component was identified.

Operative technique. All the procedures were performed using the anterolateral Watson-Jones approach with the patient supine. A trochanteric osteotomy and lateral repositioning of the trochanter was performed when excessive femoral anteversion was defunctioning the abductor muscles. The true acetabulum was identified intraoperatively by placing a retractor at the level of the teardrop. A Hillock revision uncemented titanium alloy, hydroxyapatite (HA)-coated acetabular component (Symbios, Yverdon, Switzerland) was used in every case. This implant has an obturator hook, two superolateral screws in the acetabular roof and a conventional Ultra High Weight Polyethylene (UHWPE) insert. The inner diameter of the modular insert was 22 mm, 28 mm or 32 mm. It is intended that the hook of the cementless ring be placed at the level of the teardrop, so that attempted placement of the acetabular component is at the anatomical hip centre. Any superolateral acetabular defect was filled with autogenous resected superior femoral head allograft to obtain more than 80% cover of the acetabular component. This was required in 11 patients. A stainless-steel rasp of the same geometry as the femoral stem was used to prepare the femur, allowing compaction of the cancellous bone. A custom HA-coated cementless titanium femoral component fitting the intramedullary proximal femoral anatomy and accommodating the offset of the femoral neck to obtain the correct hip centre was then inserted (Figs 1 to 3). The femoral component was designed to produce proximal loading on the femur with intimate bone contact to obtain primary stability, and was tapered distally to avoid stress shielding and femoral fracture during insertion (Fig. 3).

No proximal femoral shortening osteotomy was performed, but tenotomies of either the adductors or the psoas were performed sequentially to achieve appropriate lengthening while reducing the risk of neurological complications. In Crowe grades III and IV, once the psoas insertion was released, the femoral head/neck resection osteotomy could be performed at the level of the lesser trochanter to ensure a circumferential capsule detachment.
Described by DeLee and Charnley, Engh and Bobyn, osseointegration of the femoral component according to Stauffer, and the Brooker et al. acetabular-bone interface according to DeLee and Charnley. The presence of intra- or post-operative complications, including infection, nerve palsy or dislocation, was recorded.

Post-operatively, the same radiological protocol, including an AP view of the pelvis, AP and lateral views of both hips and a full-length AP view of both legs, was carried out on all patients. These radiographs allowed analysis of the new centre of hip rotation according to the method of Hirakawa et al.,21 the leg-length discrepancy, the abductor lever arm ratio as described by Amstutz and Sakai,22 the osseointegration of the femoral component according to Engh and Bobyn,23 the presence of radiolucent lines at the acetabular-bone interface according to DeLee and Charnley,24 the stability of the acetabular component as described by Zicat, Engh and Gokcen25 in each of the three zones described by DeLee and Charnley,24 linear acetabular wear according to Stauffer,26 graft osseointegration according to Conn et al.27 and the Brooker et al.28 grade of heterotopic ossification. All these analyses were conducted by an independent assessor (XF). The magnification was determined from the known diameter of the implanted prosthetic head.

Statistical methods. Quantitative data were expressed in means and ranges. Statistical analysis was undertaken using the chi-squared test or Fisher’s exact test for qualitative data. Statistical significance was defined as a p-value < 0.05. The cumulative probabilities of revision were estimated using the Kaplan-Meier product limit method, with the endpoint defined as revision of the femoral or acetabular component for any reason, with a 95% confidence interval (CI). No attempt was made to correlate implant survivorship with factors such as age, gender, body mass index or previous surgery. The paired t-test was used for quantitative data.

Results

The mean femoral anteversion was 38.6° (2° to 86°) with a mean correction in the prosthetic neck of -23.6° (-71° to 13°). The mean prosthetic neck-shaft angle was 131.8° (102° to 143°). The AP diameter of the true acetabulum was 51 mm (37.5 to 64). There did not appear to be any relationship between these values and the degree of subluxation.

A trochanteric osteotomy was performed in 20 hips (20.6%). Suprolateral grafting of the acetabulum using bone from the femoral head was necessary in 11 hips (11.3%).

There was a statistically significant improvement in the mean HHS from 58 points (15 to 84) pre-operatively, to 93 points (40 to 100) post-operatively (paired t-test, p < 0.001): respectively, pain 39 (13 to 44), walking 29.4 (10 to 33), activity 12.4 (9 to 15), deformity 2.9 (1.5 to 4) and range of motion 3.6 (2 to 5). Two nerve palsies occurred, one involving the sciatic and one the femoral nerve, which resolved at 18 and 11 months, respectively. Post-operative dislocation occurred in three patients (three hips, 3%), one of which required an open reduction and the other two, revision of the acetabular component.

The mean height of the centre of the prosthetic head relative to the teardrop was 23.4 mm (9 to 47) and the mean horizontal location of the prosthetic femoral head centre was 30.4 mm (23 to 42). The mean post-operative leg-length discrepancy was 2.4 mm (0 to 34). According to Amstutz and Sakai,22 the abductor lever arm ratio was normal in 80 hips (82.4%).

Analysis of the proximal femur showed increased endosteal density in 84 hips (86.6%), a non-progressive radiolucent line in eight hips (8.2%) who had no thigh pain, and asymptomatic osteolysis in five hips (5.2%) in zone 1.29 In addition, we observed eight hips with cortical hypertrophy (8.2%), three with incomplete cortical bone bars (3%), direct contact between the femoral component and the femoral cortex in 18 hips (18.6%) and in one, contact shown on the AP and the lateral radiographs. This patient experienced thigh pain. Peri-articular heterotopic ossification (HO), classified as Brooker grade 1 or 2 was found in seven hips (7.2%).

One acetabular component, which had been secured with 80% of its support provided by bone graft as viewed on the AP radiograph, demonstrated early migration to a more vertical and medial position with breakage of one of the fixation screws. However, the position of the component did not change further with time and, at the latest 11-year radiological follow-up examination, it appeared well fixed without a complete radiolucent line and no graft resorption. All the remaining acetabular components were located in the true acetabulum without detectable migra-

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tion. A non-progressive radiolucent line was found around the acetabular components of five patients involving DeLee and Charnley, zone I in three and zone II in two. The mean total linear acetabular wear was 0.5 mm (0 to 2.5) and the mean annual linear acetabular wear was 0.06 mm per year (0 to 0.54). The wear did not correlate with the severity of subluxation (paired t-test, p = 0.057). According to Conn et al., all the bone grafts showed evidence of integration at the time of follow-up, with a homogeneous density and no radiological interface between the host bone and the graft in ten of the 11 patients who had required a graft.

In six hips (6.2%) a revision was needed. In four the acetabular component was revised, one required an isolated femoral revision and one had revision of both components for sepsis. The four acetabular revisions included two patients with aseptic loosening following polyethylene wear at 85 and 91 months respectively. The other two had recurrent dislocation, including a 69-year-old woman with Crowe grade II dysplasia who underwent acetabular revision at 17 months, and a 57-year-old man with Crowe grade III dysplasia, at 14 months. Of the two femoral revisions, one was for septic loosening at 22 months and required a two-stage revision, the other occurred in a 49-year-old woman who had previously undergone four procedures on the hip and sustained a fracture of the femur at six months.

The Kaplan-Meier survival for revision of the femoral component for any reason was 97.4% (95% CI 97.1 to 97.7) at 13 years when two hips were at risk. Considering revision of either component for any reason, the survival rate was 89.5% (95% CI 89.2 to 89.8) at 13 years when two hips were at risk.

Discussion
Patients with OA following congenital hip disease undergo THR at a younger age than those with idiopathic OA. The major technical problems encountered are the reconstruction of the dysplastic acetabulum, placement of the femoral component into the extremely narrow diaphysis, restoration of the lever arm and leg length, and finally the accommodation of excessive femoral anteversion. These latter extramedullary features have been the authors’ primary reason for using a custom-made femoral component in which the three-dimensional design of the femoral neck is able to correct these abnormalities. We describe the use of cementless custom-made femoral components for this problem in a large group of patients followed up to a mean of ten years, during which time only 19 hips of 116 were lost to follow-up.

The survival rate without acetabular revision for any reason was 89.5% (95% CI 89.2 to 89.8) at 13 years and compares favourably with results of cemented components. However, adequate cover of the acetabular component is essential for secondary bone ingrowth and durable fixation and remains a difficult part of the procedure. Jasty, Anderson and Harris preferred to place the component in the false acetabulum, requiring extra-long necks with a risk of residual discrepancy in leg-length or instability of the hip. Furthermore, proximal or lateral placement of the acetabular component has been described as a risk factor for loosening of both the femoral and the acetabular components because joint loading is greater in the superolateral than in the inferomedial position. In order to avoid bone grafting, the medial protrusio technique has also been described, with adequate results. However, inadequate medialisation of the centre of the hip reduces the force of the abductor muscles and may compromise long-term results. We believe that the acetabular component should be placed in the true acetabulum in order to obtain better cover, and reduce leg-length discrepancy, abductor insufficiency, incidence of loosening and wear rate. Acetabular reconstruction was carried out using a cementless reinforcement ring and autologous bone grafting when necessary. We were able to place the centre of the hip close to normal in the present study which, together with the femoral reconstruction with a custom-made component, allowed the correction of leg length and restoration of the lever arm.

The use of cemented femoral components has been described in hip dysplasia with encouraging medium- and long-term results. The difficulty of securing femoral components in an extremely narrow medullary cavity with space for only a thin mantle of cement has been noted. Huo et al have reported the use of custom-designed components with cement in 19 dysplastic hips in 14 patients with survival of the femoral component of 93% at nine years.

There are reports of conventional femoral cementless components used in THR for hip dysplasia. In a series of 121 THRs with a straight cementless stem with a 9.3-year survival rate of 97.5%, 20 hips required an additional osteotomy and seven femoral fractures occurred. Oh et al studied the outcome of THR in 12 cemented and 40 cementless hips using miniaturised anatomical medullary locking stems for hip dysplasia or juvenile arthritis, observing that proximal stress shielding occurred in 39 of the 40 femora that underwent cementless fixation.

In cementless THR, the need to optimise the filling of the femur has become apparent. A proximal fitting stem requires intimate metaphyseal bone contact, which is difficult in developmental dysplasia of the hip because of the narrow antverted femur. Gosens et al described good results with a cementless proximal loading stem for THR in 63 cases of hip dysplasia without a specially-designed prosthesis, but in two patients a proximal femoral splitting osteotomy was required.

A femoral osteotomy associated with a cementless stem has also been previously described in THR for congenital dislocation. However, nonunion of the osteotomy site can occur.
Modular uncemented femoral implants have been used in THR for dysplastic hips, but modular designs may introduce additional problems related to corrosion, fretting and dislocation or fracture of the components. The maximum amount of lengthening that can be safely performed without neurological damage remains uncertain, with no proven relationship between it and the occurrence of nerve injury. In the present study, the mean lengthening was 2.5 mm (5 to 58) with only two transient nerve palsies.

This study has shown that a custom-made cementless femoral component accommodating the proximal fit and correcting both anteversion and frontal offset may represent a valuable option for THR in congenital dislocation of the hip. This avoids the risks of a subtrochanteric osteotomy and allows immediate weight-bearing. The 97.4% of survival rate of the hip is encouraging for this young and active population.

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