CLINICAL RESEARCH

Femoral Shortening in Total Hip Arthroplasty for High Developmental Dysplasia of the Hip

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Abstract

Background When reconstructing a hip with developmental dysplasia with a high dislocation, placing the acetabular component in the anatomic position can result in a prosthetic hip that is difficult to reduce. Subtrochanteric femoral osteotomy and shortening makes reduction easier but can be associated with complications (eg, limp, sciatic nerve injury, nonunion of the osteotomy) or compromise long-term stem survival.

Questions/purposes We therefore evaluated (1) the short-term complication rate, (2) functional scores, and (3) survivorship of prostheses in patients with high developmental dysplasia of the hip reconstructed with femoral shortening.

Patients and Methods We prospectively followed 46 patients (65 hips) operated on from 1990 to 2000. There were 34 females and 12 males with a mean age of 48 years (range, 16–79 years). Before surgery, all patients had a positive Trendelenburg test. The minimum followup was 8 years (mean, 13 years; range, 8–18 years).

Results One patient experienced recurrent dislocation and two peroneal nerve palsies, one of which partially recovered and one of which was permanent. In one patient, the stem subsided and after 8 months was replaced by a larger stem that stabilized. One patient had a nonunion but was functioning well and did not have additional surgery. At followup, 12 of the 65 hips (18%) had a positive Trendelenburg test. The mean muscle strength of the abductors was 4 (range, 3–5). The mean Harris hip score was 87 (range, 59–100) and the mean visual analog scale pain score 81 (range, 35–100). At followup, all stems were well fixed with no obvious signs of radiographic loosening. Ten cups were revised because of aseptic loosening.

Conclusions Our data suggest femoral osteotomy and shortening at the subtrochanteric level predictably allows a stable reduction in patients with high developmental dysplasia of the hip and does not lead to any reduction in long-term survival.

Level of Evidence Level II, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

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Introduction

In high developmental dysplasia of the hip (DDH), the femoral head has migrated superiorly (and posteriorly) relative to the true acetabulum and articulates with a concavity in the iliac wing, which takes the form of a false acetabulum. In one radiographic study of three-dimensional anatomic parameters in 247 adult dysplastic hips [1], the true acetabulum had a mean reduced diameter, the intramedullary femoral canal was smaller, and the proximal femur had more anteversion compared with 310 hips with primary osteoarthritis. When reconstructing a hip with a high dislocation, it sometimes is difficult to identify the true acetabulum and reduce the prosthetic hip located in the true acetabulum because the soft tissues are contracted owing to the chronic dislocation.

To overcome the contractures and to reduce the hip without stretching the sciatic nerve, femoral shortening has been advocated as an adjunct to THA. A traditional method has been to perform osteotomy at the proximal part of the femur with distal advancement of the greater trochanter [9, 13]. However, to preserve the proximal femoral anatomy, and to avoid the problems associated with reattachment and healing of the greater trochanter, subtrochanteric [2, 18, 20, 27], diaphyseal [23], or distal [19] shortening osteotomy of the femur have been described. Disadvantages of osteotomy are the risk of fracture or nonunion. Furthermore, recurrent dislocations may occur, and overall the rate of complications has been reported to range from approximately 15% to 40% [2, 9, 18, 20, 23, 27].

Since 1990, we have performed subtrochanteric shortening osteotomy of the femur and implantation of uncemented prostheses in patients treated for high DDH. The rationale for the use of the uncemented prosthesis was to avoid introducing cement at the osteotomy site, which might interfere with healing.

We evaluated (1) the rate of short-term complications, (2) functional scores, and (3) survivorship of prostheses in patients with high DDH reconstructed with femoral shortening.

Patients and Methods

We retrospectively reviewed 46 prospectively followed patients (65 hips) in whom THA was performed for high DDH from 1990 to 2000. There were 12 males and 34 females with a mean age of 48 years (range, 16–79 years). The indications for arthroplasty were severe pain and/or functional impairment with difficulty in walking and performing daily activities. Twenty patients had bilateral high dislocations, 13 had high dislocation of one hip and

dysplasia of the other, and 13 had high dislocation of one hip and normal development of the other. Before surgery, the mean leg length discrepancy was 3 cm (range, 0–8 cm). Two patients had previous Schanz osteotomy, and one had a cemented Charnley prosthesis with a high hip center with subsequent cup loosening. During followup, two patients died, and these were censored at their last control examination; no patients were lost to followup. The minimum followup was 8 years (mean, 13 years; range, 8–18 years). The study was performed in accordance with the Helsinki Declaration.

All operations were planned with transparencies. The acetabulum was placed at its natural level, and the femur was correspondingly inferiorized. The amount of femoral shortening was determined by an amount that would not lengthen the leg more than 4 cm to avoid stretching of the sciatic nerve; in most cases, it was 2 to 3 cm (Fig. 1). We used either a direct lateral or posterior approach with the patient in the lateral position. The femoral neck was transected and the canal reamed. We then performed a transverse osteotomy just beneath the lesser trochanter. The osteotomy site allowed access to the true acetabulum. The elongated hypertrophic joint capsule was resected, and the proximal parts of the pubic and ischial bones and the teardrop were exposed to assess bone stock and identify the small fibrous fatty tissue filling the true acetabulum. We began reaming with small reamers and gradually enlarged the acetabular recess to contain a cementless component that could be fixed with two to three screws. If the acetabular roof was defective, we reinforced it with bone graft from the removed femoral head. The pelvic contact bed for the graft was denuded of soft tissues, and sclerotic bone perforated with a chisel or by careful reaming. The cartilage and subchondral bone then were removed from the femoral head before it was shaped with an oscillating saw to fit the contact bed with its cancellous surface and fixed

Fig. 1A–B (A) A radiograph shows the preoperative templating process. Reduction of the hip center is 6.5 cm, and subtrochanteric shortening (between the blue osteotomy lines) is 4 cm. (B) A postoperative radiograph shows the result.
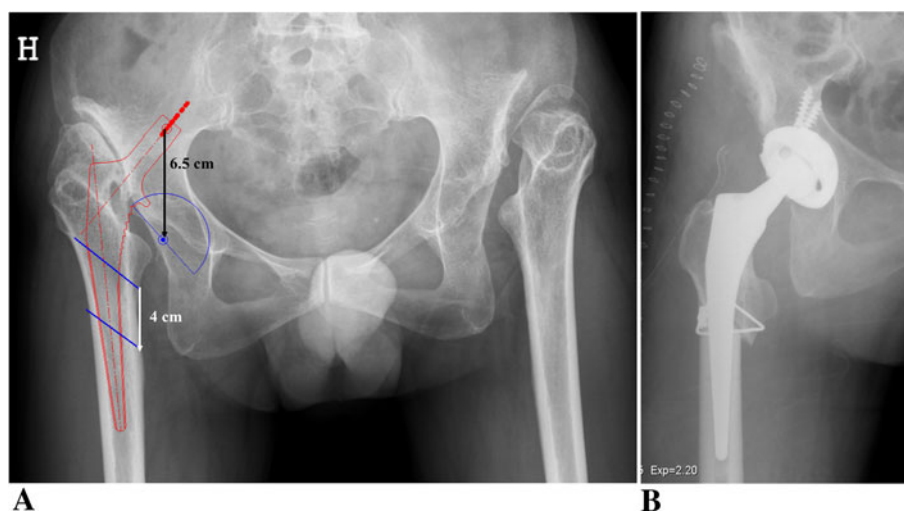
with cancellous screws. After grafting, additional reaming of the acetabular recess was performed to establish continuity of the contour from intact bone to the adjacent graft. In some hips, when less than 80% of the cup could be covered by host bone, the central part of the medial wall was fractured intentionally and pushed medially with its periosteal attachments preserved [15]. No more than 25% of the medial area of the acetabulum was displaced, and it was augmented with reamed cancellous bone. The acetabular component was impacted against the medial wall and fixed with screws to the circumferential support.

After the acetabular component was seated, excessive femoral anteversion was corrected by derotation, thereby correcting the posterior position of the greater trochanter. The amount of shortening subsequently was performed as preoperatively planned. This was performed by either oblique (n = 41) (Fig. 2) or step-cut (n = 24) osteotomies to stabilize against rotation. After removal of the segment of bone, we again reamed the distal femoral canal to fit a trial stem. If reduction proved impossible, the trial stem was inserted only in the proximal part of the femoral bone and reduced in the acetabulum. Traction was applied to the extremity, the proximal and distal fragments of the femoral bone were overlapped, and additional resection of bone was performed as needed. We used no anesthetic paralytics in this procedure. The femoral component was inserted with press fit; the osteotomy site generally was not grafted. However, if there was some gap at the osteotomy site, this was filled with cancellous bone from the femoral head.

In all hips, we used a straight stem designed for press-fit insertion (Landanger, Chaumont, France). The component was made of grit-blasted $TiAl_6V_4$, and the outer surfaces were entirely plasma-sprayed with a 155 ± 35-μm layer of hydroxyapatite (HA) (technical data provided by the manufacturer). The purity of the HA reportedly was greater than 97%, the density between 1.2 and 1.6 g per mL, the crystallinity greater than 50%, and the porosity less than 10%. The surface roughness of the coating was characterized by an Ra (arithmetical mean roughness value) between 7.5 and 9.5 μm and Rt (maximum profile height) between 50 and 65. The surface roughness of the grit-blasted metal was characterized by an Ra between 4 and 6 μm and Rt between 25 and 40. The bonding strength of the coating to the metal was reportedly more than 10 MPa. We used sizes 7 to 14 stems.

We used a hemispheric cup (Landanger) inserted with press fit in 23 hips and a screw cup (Landanger) in 14 hips. Both were made of grit-blasted $TiAl_6V_4$, and the outer surfaces were entirely plasma-sprayed with HA like the stem. In 16 hips, we used a hemispheric cup designed for press fit, made of $TiAl_6V_4$, and coated with a mesh of pure titanium (Zimmer, Inc, Warsaw, IN). We used sizes 36 to 56 cups.

At surgery, the hip center was inferiorized by a mean of 7 cm (range, 3–10 cm) to the level of the real acetabulum. The mean shortening of the femur was 5 cm (range, 2–8 cm), and the mean leg lengthening was 3 cm (range, 1–4 cm).

Fig. 2A–D (A) A preoperative radiograph shows high bilateral DDH in a 39-year-old patient. (B) A postoperative radiograph shows the hips after femoral shortening and THA on the left side. (C) A postoperative radiograph after 1 year shows healing of the osteotomy and incorporation of the prosthesis. (D) A postoperative radiograph 3 months after surgery on the right side shows successful implantation of prostheses on both sides.
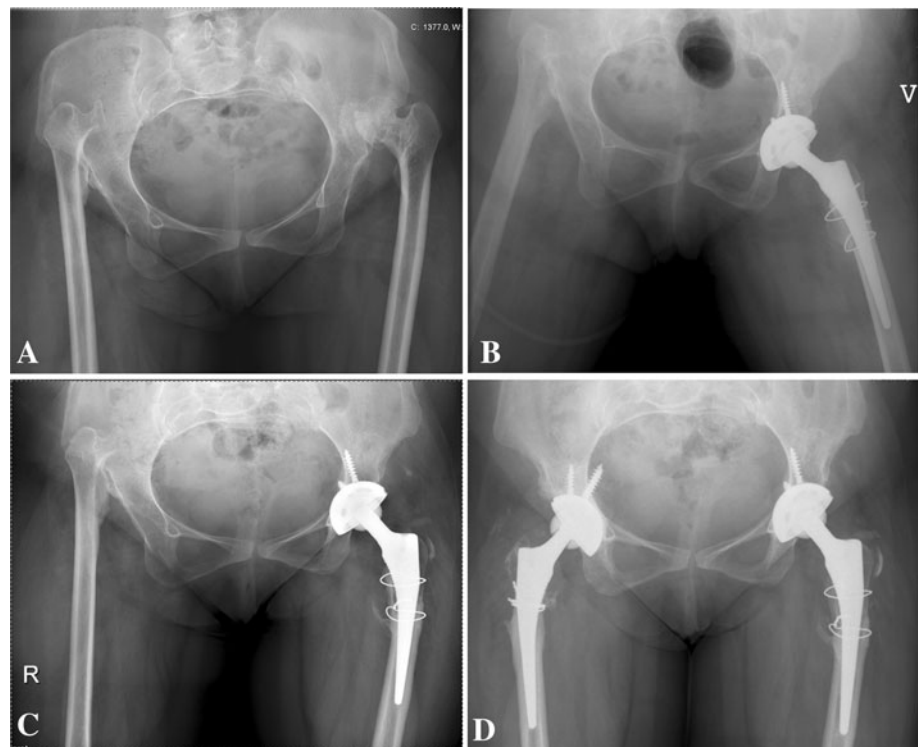
We allowed partial weightbearing (15–20 kg) with crutches during the first 3 months postoperatively, with progression to full weightbearing the following weeks. During the hospital stay for a week, the patients' gait was supervised by a physiotherapist, but the patients had no specific training.

We followed patients 3 months after surgery, at 1 year, and thereafter every other year. We clinically rated all patients at each visit using the Harris hip score [12]. In addition, pain was measured on a visual analog scale (VAS) from 0 (strong pain) to 100 (no pain). One of us (OR, JEH, PL) measured abduction strength of the hip. First, the patient was asked to elevate the affected extremity against resistance by the physician's hand, and the strength of abduction of the hip was graded according to the standard Medical Research Council scale (MRC Grades 0 through 5) [29]. Then, abduction strength was assessed with the Trendelenburg test.

At each visit, we obtained a supine AP radiograph of the pelvis with both hips in neutral rotation and abduction and a lateral radiograph of the hip. Three of us (OR, PL, JEH) made linear measurements on the AP radiograph using a caliper and corrected by reference to the diameter of the femoral head. Polyethylene wear was measured according to Livermore et al. [22]. Radiographic bony incorporation was defined as extensive intimate bone-implant contact, periprosthetic bone formation and remodeling, and the absence of migration. A radiodense line that approximately paralleled the surface contour of the implant but was separated from it by a total radiolucent zone (line) of varying thickness was classified as fibrous ingrowths. Focal area of bone loss was considered evidence of osteolysis [32]. Appearance of radiolucent lines and osteolytic lesions were documented and classified on the basis of size and regional location according to DeLee and Charnley [4] and Gruen et al. [11] on the femoral side. We modified the criteria of Massin et al. [25] for cup loosening, using a variation greater than 5 mm or 5°. Subsidence of the femoral component was referenced by the vertical distance from the tip of the trochanter to the lateral shoulder of the prosthesis, using a variation greater than 5 mm. This limit of migration was set arbitrarily but was based on analysis of manual measurements of migration of hip prostheses [24].

A Kaplan-Meier survival analysis [17] was performed with removal of component as the end point.

Results

Two patients experienced peroneal nerve palsy with dropfoot; one patient had partial recovery, and the other had none. In one patient, the stem subsided through the postoperative period, and after 8 months, it was replaced by a

Fig. 3 A radiograph shows the hip of the patient with established pseudarthrosis 17 years after THA.

larger stem that incorporated. One patient had revision surgery with a longer neck being implanted owing to recurrent dislocations; another was treated successfully with bone transplantation owing to delayed union of the osteotomy; and a third patient had pseudarthrosis develop at the osteotomy site but fared well and would not undergo reoperation (Fig. 3). One patient fell 2 months after the operation and sustained a periprosthetic fracture around the stem. The fracture was stabilized with a longer stem, with full healing and incorporation of the stem. At followup, the mean limb length discrepancy was 1 cm (range, 0–3 cm), and the Trendelenburg test was negative in 53 hips and positive in 12. The mean muscle strength of the abductors was 4 (range, 3–5).

At last followup, the mean Harris hip score was 87 (range, 59–100), and VAS pain score averaged 82 (range, 35–100).

The cumulative cup survival was 0.75 (95% confidence interval, 0.57–0.93) at 15 years (Table 1). At followup, the stems were integrated with no obvious signs of radiographic loosening. No stems had subsided. Radiolucent lines were observed in four hips in Zone I, and focal osteolysis was observed in three hips in Zone I. Osteolysis was associated with wear. Ten cups were revised because of mechanical loosening: six hemispheric HA-coated cups, two HA-coated screw cups, and two hemispheric porous-coated cups. One patient sustained a fracture of the acetabulum after 9 years with revision and bone transplantation. Radiographic analyses of the surviving cups revealed radiolucency in Zone I in one hip and in Zone III

Table 1. Kaplan-Meyer survival for the acetabular component

Time (years)	Cumulative survival (95% CI)
8	0.97 (0.93–1.0)
9	0.95 (0.90–1.0)
10	0.92 (0.85–0.99)
11	0.89 (0.81–0.97)
12	0.89 (0.81–0.97)
13	0.86 (0.78–0.95)
14	0.83 (0.73–0.94)
15	0.75 (0.57–0.93)

CI = confidence interval.

in five hips. Focal osteolysis was observed in Zone I in one hip and in Zone III in two hips, but otherwise the cups showed bony incorporation as indicated by intimate bone-implant contact.

Discussion

In DDH with high dislocation, the anatomy is markedly distorted by the soft tissue contracture, inadequate bone stock, abnormal location of the hip center, abnormality of the neurovascular structures, and leg length discrepancies. With these abnormalities, it is difficult to achieve and maintain reduction in the true acetabulum. Subtrochanteric femoral osteotomy and shortening is one approach that makes reduction easier but can be associated with complications (eg, limp, sciatic nerve injury, nonunion of the osteotomy) or compromise the long-term survival of the stem. We therefore evaluated (1) the rate of short-term complications, (2) functional scores, and (3) survivorship of prostheses in patients with high DDH reconstructed with femoral shortening.

There are limitations to our study. First, we used three different acetabular cups but did not have adequate numbers to determine whether the revision rates differed among these three cups. Second, we performed no interobserver and intraobserver variability of the radiographic evaluations, although these would not influence the survival data.

Common complications in femoral shortening osteotomy are fracture and nonunion at the osteotomy site. Intraoperative fracture during insertion of the femoral component has been reported to range from 5% to 22% [2, 8, 9, 18, 20], and nonunion has been reported to vary between 8% and 29% [13, 14, 30]. We identified no perioperative fractures and speculate the prophylactic use of cerclage wiring minimized that risk. One patient underwent reoperation and bone transplantation after a year for delayed union of the osteotomy, and one patient had pseudarthrosis with a positive Trendelenburg test. In

another three hips, there was some migration of the trochanter segment before successful union, but with no relationship to dislocation. Only one patient experienced recurrent dislocations and was treated successfully with change to a head with a longer neck. Recently Krych et al. [20] reported femoral fractures occurred in five of 28 hips, and nonunions at the subtrochanteric osteotomy site developed in two. Altogether 12 hips (43%) had an early or late complication or reoperation. At followup (mean, 4.8 years), the Harris hip score was on average 89 points. Our complication rate was 9%, and our mean Harris hip score at followup was 87.

Generally, prior reports of femoral shortening osteotomy in DDH have included mixed groups of cemented and cementless components, and most of the studies have a small number of patients or a short followup with a minimum less than 5 years. There are only a few studies with a longer followup. Eskelinen et al. [9] followed 64 of 75 hips in patients with uncemented components for a mean of 12 years. The Harris hips score was on average 84. The 10-year survival rate was 94% for the stem and 88% for the cup, but eight of nine threaded cups were revised. Hartofilakidis and Karachalios [13] followed 84 hips with uncemented cups and cemented stems for a minimum of 7 years. Survivorship analysis predicted an overall 15-year survival rate of 76% (86% for the cup and 82% for the stem). Kim et al. [18] followed 62 hips with high dislocation after childhood sepsis for 13 to 17 years. The Harris hips score was on average 89, and the 15-year survival rates of the uncemented acetabular and femoral components were 94% and 95%, respectively. Our results agree with these observations (Table 2).

Previous findings have suggested superior positioning of the acetabular component in dislocations of the hip leads to increased rates of loosening. Linde et al. [21] followed patients who underwent 129 consecutive Charnley arthroplasties for osteoarthritis secondary to dysplasia of the hip. Up to 15 years, mechanical loosening of the acetabular component was 42% in the group in which the component was placed proximal to the true acetabulum and 13% in the group in which it was placed at the anatomic level. Pagnano et al. [26] found positioning of the cup proximal to the true acetabular region was associated with substantial increase in loosening. However, Hartofilakidis and Karachalios [13] placed all acetabular components in the anatomic position with no differences in 15-year survival between the patients with dysplasia, low, or high hip dislocation. These observations indicate the acetabular component should be positioned in the true acetabular region in patients with high DDH.

It is generally accepted the survival of THA implants in an elderly and inactive population are not replicated in younger and more active patients. In patients younger than

Table 2. Study results of THA in high DDH and dislocation

| Study | Number of hips | Age of patients (years) | Followup (years) | Number of complications | | | | | Mean Harris hip score | 15-year survival | |
				Nerve injury	Dislocation	Fracture	Nonunion	Other		Cup	Stem
Kim et al. [18]	62	22–66	13–17	2	3	3	0	1	89	94%	96%
Hartofilakidis and Karachalios [13]*	84	23–70	7–15	2	4	0	19	Not given	Not given	86%	82%
Eskelinen et al. [9]	75	Not given	9–15	5	2	5	Not given	1	84	88%[†]	94%[†]
Current study	65	16–79	8–18	2	1	0	2	1	87	75%	100%

* Hartofilakidis and Karachalios [13] used a cemented stem; otherwise uncemented components were used; [†] at 10 years

50 years at the time of surgery, the revision rate has been reported to vary from 18% to 39% at a followup of 5 to 12 years [3, 7]. Dorr et al. [5] followed 49 hips in patients younger than 45 years, and the revision rate increased from 12% at 5 years to 33% at 9 years to 67% at 16 years. Also, there are major technical problems in fitting the components in an underdeveloped acetabulum and a narrow diaphysis in cases of high DDH. Small implants are regularly needed with consequently thin liners. We mostly used a hemispheric cup coated with HA, and previously reported a high rate of mechanical loosening of this cup in younger patients with osteoarthritis with a survival of 0.74 at 15 years [28]. This is comparable to the revision rate in the current series of patients. Furthermore, Eskelinen et al. [9] reported a lower survival rate for threaded cups than for porous-coated hemispheric cups. Our high rate of loosening of the cup, therefore, to a high degree can be ascribed to inferior cup designs. On the femoral side, we used a stem with a rectangular shape for rotational stability. Optimal canal fit and fill are necessary for primary stability and bone ingrowth. The absence of radiolucent lines in the diaphysis of the stems suggests a comprehensive diaphyseal bonding in our patients at followup.

Limb length discrepancy is one of the main problems in dysplastic hip arthroplasty. In bilateral cases, we aimed to lengthen both hips by approximately 2 cm, but in unilateral cases, we aimed to lengthen more, but not exceeding 3 to 4 cm. During the operation, it is difficult to estimate the optimal amount of lengthening, and our estimations were based on bone shortening in relation to preoperative templating. Sciatic neuropathy has been reported in patients in whom distal positioning of the acetabular cup was a major goal [6, 16]. Postoperatively, we positioned the extremity with the hip extended and the knee flexed to reduce tension on the sciatic nerve. Certain preoperative factors are identified to place the patient at risk for having nerve injury develop during THA [10]. A preoperative diagnosis of posttraumatic arthritis or DDH, use of a posterior approach, cementless fixation, and excessive limb lengthening all increase the odds for nerve palsy. Operative trauma or

traction on the nerve by soft tissue adherences are also factors because the incidence of nerve injury is greater in difficult than in routine arthroplasties [6, 16].

A hip with high DDH can be lax and painless, and preoperative evaluations of the hip function according to Harris hip score may be unreliable. In the followup evaluations, however, we used the Harris hip score. A mean Harris hip score of 88 after THA was reported for patients at a younger age who had osteoarthritis [31], and the Harris hip and VAS pain scores in these patients were similar to those for the current patients.

Subtrochanteric shortening osteotomy with distal advancement of the trochanter segment is a predictable adjunct to THA in patients with high DDH. The complication rate is high, but complications resolve in most patients and the patients have high mean functional scores and high midterm survival.

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