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Long-Term Results of Cemented Total Hip Arthroplasty in Developmental Dysplasia With Acetabular Bulk Bone Grafts After Improving Operative Techniques

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Abstract: We present the long-term results (mean follow-up, 11.8 years; range, 6.3-15.4 years) of cemented total hip arthroplasty with acetabular bulk bone grafting in 147 dysplastic hips using improved surgical techniques. Operations were performed through a direct lateral approach with partial trochanteric osteotomy to avoid nonunion of the greater trochanter. Bioresorbable poly(L-lactide) screws were used for fixation of the acetabular bone grafts to prevent any possible delayed remodeling. Preoperative planning using computer simulation was performed to estimate the optimal size and position of the acetabular component. Analysis predicted rates of survival of the acetabular component of 96% and 91% at 15 years, with revision for aseptic loosening and radiologic loosening as the end points, respectively. Our results indicate excellent long-term clinical and radiographic survivorship of a cemented acetabular component with bulk autograft for acetabular dysplasia. **Keywords:** total hip arthroplasty, long-term results, acetabular autogenous bulk bone graft, improved operative techniques.

Total hip arthroplasty (THA) is a successful procedure for the restoration of hip joint function and the relief of pain for patients with osteoarthritis. Many midterm and long-term follow-up evaluations of THA have been reported, leading to several improvements in operative techniques [1-5].

Total hip arthroplasty in patients who have developmental dysplasia of the hip often requires autogenous bulk bone grafting to augment the acetabular bone defect when the acetabular component is placed at the level of the true acetabulum. This procedure is satisfactory in the short-term, but the results in the long-term have been much more variable [6,7]. We previously reported the long-term results of cemented THA with acetabular bulk bone grafting for developmental dysplasia performed between 1974 and 1988 [8]. Kaplan-Meier analysis predicted a rate of survival of the acetabular component at 15 years of 96% with revision for aseptic loosening as the end point and 75% with radiologic loosening as the end point. We identified the risk factors that were responsible for loosening of the acetabular component as follows: trochanteric nonunion, lateral placement of the acetabular component, and delayed trabecular reorientation of the grafted bone.

To improve the long-term results, we used a direct lateral approach, instead of a transtrochanteric approach, to prevent nonunion of the reattached greater trochanter and used bioresorbable poly(L-lactide) screws to fix the acetabular grafts, instead of crystalline alumina ceramic screws. Furthermore, we performed preoperative planning using computer simulation, which is valuable for placing the acetabular component more accurately at the level of the true acetabulum. In this study, we show the long-term success of cemented THAs with acetabular bulk bone grafting for developmental dysplasia of the hip using this improved surgical protocol.

Patients and Methods

Between 1991 and 1997, we performed 254 primary cemented THAs using the PHS KC prosthesis (Japan Medical Materials Corp, Osaka, Japan) with a 22-mm alumina ceramic head (Fig. 1A). During this period, 119

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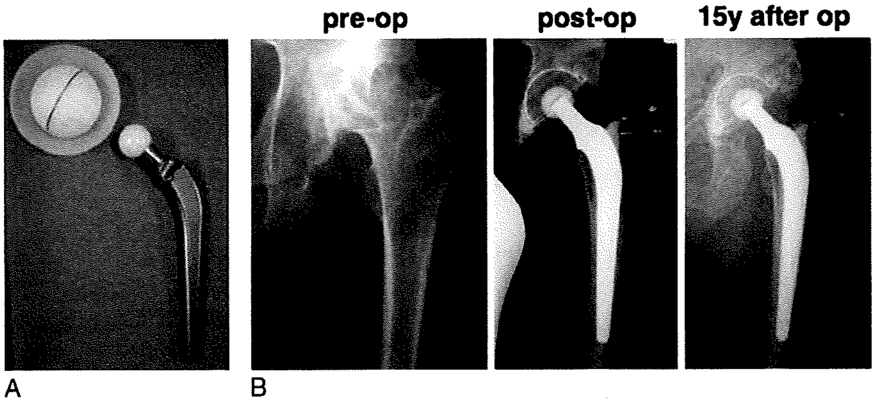

Fig. 1. (A) Photograph showing a PHS KC prosthesis and a 22-mm alumina ceramic head. (B) Radiographs taken preoperatively, postoperatively, and at 15 years after surgery.

patients (147 THAs) required acetabular bulk bone grafting and were observed for an average of 11.8 years (range, 6.3-15.4 years) forming the study group.

The patients consisted of 7 men and 112 women, with a mean age at the time of the operation of 56 years (range, 38-76), a height of 150.6 ± 5.7 cm, and a weight of 51.6 ± 7.9 kg. The diagnosis for all hips at the time of operation was secondary osteoarthritis caused by developmental dysplasia or congenital dislocation of the hip. The degree of subluxation was categorized according to Crowe et al [9] as shown in Table 1.

Before surgery, computer simulation for the planning was performed as described [10]. Briefly, images of hip joint computerized tomography with a line interval of 5 mm were entered into the computer using a digital camera. The level of the acetabular component center was decided from the original acetabulum. The diameter, the location of the component, the inclination angle, and the anteversion of the component were determined in relation to the anteroposterior diameter of the acetabulum and the thickness of its anterior and posterior lips. The area in need of a bone graft was shown by a line that represented the lateral half contour of the projected image of the component in the horizontal plane.

All operations were performed through a direct lateral approach with partial trochanteric osteotomy as reported by Dall [11]. The acetabular autogenous bone grafting using the resected femoral head was done as described by Wolfgang [5]. The grafts were fixed to the superolateral aspect of the acetabular roof with bioresorbable poly(L-lactide) screws in 113 hips, titanium screws in 17, and AO stainless steel cancellous screws in 7. All the acetabular components were fixed with CMW1 radiopaque cement (CMW Laboratories, Devon, United Kingdom), and all the femoral components were with CMW1 or CMW3 radiopaque cement. The cements were prepared by vacuum mixing and were applied into the femoral canal using a cement gun with autogenous bone chips packed into a femoral medullary canal as a bone plug.

Standard radiographs were taken after surgery and at 2, 4, 6, and 8 weeks; at 3, 6, and 12 months, and 6-monthly or yearly thereafter (Fig. 1B). The initial postoperative radiographs were used to measure the center and the degree of initial abduction of the acetabular components, the center-edge angle, and any lengthening of the limb. The presence of a radiolucent line around the acetabular components at the cement-bone interface in the 3 zones of DeLee and Charnley [12] was recorded. Loosening of the acetabular

Table 1. Details of the 147 THAs for Developmental Dysplasia of the Hip

Total patients	119 patients (males, 7; females, 112)
Total hip	147 hips
Mean (SD) age at operation (y)	56.3 ± 7.5
Mean (SD) height (cm)	150.6 ± 5.7
Mean (SD) weight (kg)	51.4 ± 7.9
Mean (SD) socket size (mm)	44.3 ± 2.4
Mean (SD) socket center-edge angle (deg)	5.6 ± 14.4
Mean (SD) initial abduction of the socket (deg)	40.9 ± 4.9
Mean (SD) horizontal positioning of the socket (mm)	22.1 ± 5.7
Mean (SD) limb lengthening (mm)	19.7 ± 9.6
Socket location	Superolateral, 3; superomedial, 5; inferolateral, 17; inferomedial, 122
Crowe type	
I	66
II	44
III	16
IV	21
Screw	
None	10
AO	7
Titanium	17
Poly(L-lactide)	113

component was classified according to the criteria of Hodgkinson, Shelley, and Wroblewski [13]. The criteria of Harris, McCarthy, and O'Neill [14] were used to assess radiologic evidence of loosening of the femoral component. Hip function was evaluated according to the scoring system of Merle d'Aubigné and Postel [15].

Statistical Analysis

We used the Kaplan-Meier product limit method to estimate the cumulative probabilities of revision and loosening. The survivorship curves for various subgroups were compared using the log-rank test.

Results

There were no early postoperative complications, including dislocation, nerve palsy, or infection. Nonunion of the osteotomized bone fragments of the greater trochanter occurred in 3 hips with no clinical symptoms. The mean Merle d'Aubigné and Postel hip score improved from 8.5 before operation to 15.2 at the final follow-up. Three hips required reoperation; 2 for aseptic loosening of the acetabular components. The femoral components in these patients were replaced with new components, although they had not loosened. One THA was dislocated 134 months after operation, and the femoral component was dislodged when closed reduction was tried. In this case, open reduction and femoral revision were needed. No reoperation was performed for aseptic loosening of the femoral component.

The Kaplan-Meier survivorship analysis, with revision for aseptic loosening as the end point, predicted a rate of survival of the acetabular component of 98.6% (95% confidence interval [CI], 97-99) at 10 years and 96% (95% CI, 92-99) at 15 years (Fig. 2A). For the femoral component, the rate of survival was 100% at 15 years with revision for aseptic loosening as the end point.

Radiologic Analysis: Acetabular Components

We estimated the distribution of the radiologic lucent lines around the acetabular component. Lucencies were present in 37.4% of hips in zone I, in 8.8% in zone II, and in 27.2% in zone III (Fig. 2B). At the most recent follow-up, 2 acetabular components had been revised for loosening and an additional 8 acetabular components showed evidence of radiologic loosening. The Kaplan-Meier survivorship analysis, with radiologic loosening as the end point, predicted a rate of survival for the acetabular component of 97% (95% CI, 92-98) at 10 years and 91% (95% CI, 87-94) at 15 years (Fig. 2C). Nonparametric survivorship analysis with the use of the log-rank test was applied to 9 variables as follows: the age and body weight of the patient, the size, horizontal positioning, initial abduction of the acetabular component, center-edge angle, limb lengthening, Crowe type, and trochanter nonunion. None of these parameters showed a statistically significant difference in the occurrence of radiologic loosening.

Previously, we indicated 3 risk factors that affected loosening of the acetabular component [8]. The position of the center of the acetabular component on the initial postoperative radiographs was assessed using the 4-zone

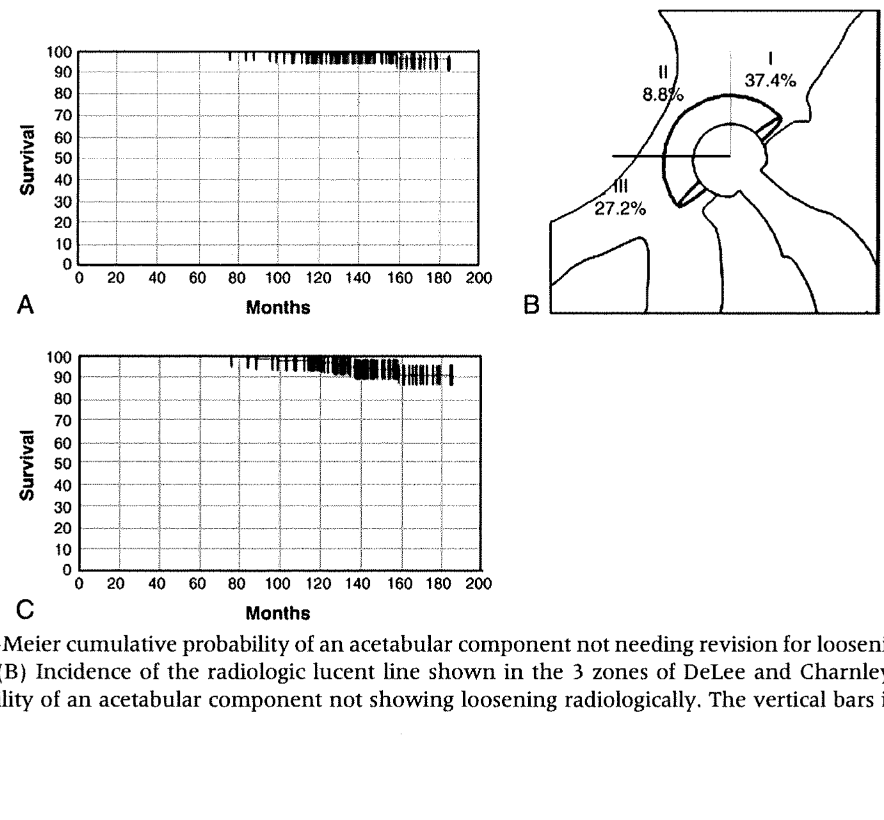

Fig. 2. (A) Kaplan-Meier cumulative probability of an acetabular component not needing revision for loosening. The vertical bars indicate 95% CIs. (B) Incidence of the radiologic lucent line shown in the 3 zones of DeLee and Charnley. (C) Kaplan-Meier cumulative probability of an acetabular component not showing loosening radiologically. The vertical bars indicate 95% CIs.

classification [16]. Fourteen percent of the acetabular components were placed laterally and 5.5% superiorly. However, in this study, comparison of the laterally placed components with all others showed no significant difference in the rate of loosening (log-rank test, $P = .8$).

In this study, we changed the operative approach from a transtrochanteric approach with wiring fixation of the detached greater trochanter to the direct lateral approach used by Dall [11]. In these cases, there were 3 hips with nonunion of the partially detached greater trochanter bone fragment, but the acetabular components of these hips were not loosened.

Previously, we fixed the grafted bone using 6.5-mm diameter crystalline alumina ceramic screws [8]. In this study, we used bioresorbable poly(L-lactide) screws to fix the grafted bones, and all the grafted bones were remodeled with trabecular reorientation within 36 months after operation. Neither nonunion nor collapse of the grafted bone was observed.

Radiologic Analysis: Femoral Components

At the most recent follow-up, no femoral component had been revised for aseptic loosening. The Kaplan-Meier survivorship analysis, with radiologic loosening as the end point, predicted a rate of survival of the femoral component of 100% at 15 years.

Discussion

Cemented THA for treating patients with a degenerative dysplastic hip using acetabular bone grafting has been controversial. We previously reported long-term results and survivorship analysis of the Charnley prosthesis and the Bioceram implant with a 28-mm alumina ceramic head with acetabular bone grafting for developmental dysplasia of the hip [8]. Kaplan-Meier survivorship analysis predicted a rate of survival of the acetabular component at 15 years of 96% with revision for aseptic loosening as the end point and 75% when radiologic loosening was used. In addition, using multivariate survival analysis with the Cox proportional hazards model, lateral positioning of the acetabular component, trochanteric nonunion, and delayed trabecular reorientation of the grafted bone were found to be risk factors for loosening of the acetabular component. From these findings, we changed our surgical techniques, resulting in a predicted survival rate of the acetabular component of 91% at 15 years with radiologic loosening as the end point. Although the large number of radiolucencies in zone I is worrisome, this is a significant improvement on our previous study.

In our revised approach, we first performed preoperative planning and simulation of placement of the acetabular component at the true acetabulum in all patients [10]. This computed tomography–based computer simulation system is useful for estimating of the optimal size of the acetabular component and determining the appropriate hip center before operation. Indeed, 20 of the 147 reconstructed acetabular centers (13.6%) were located lateral to the computer-determined center of the acetabulum. Only one component of these 20 was radiologically loosened, and there was no significant difference in the rate of radiologic loosening when assessed by log-rank test. In contrast, our previous study reported that 37 (27.8%) of 133 acetabular components were placed laterally. This showed a significant difference in the rate of radiologic loosening from those placed medially. In addition, this system enables estimation of the size and position of bone grafting. Thus, computed tomography–based preoperative planning and simulation may have contributed to the long-term survivorship of the acetabular component.

Second, to prevent nonunion of the greater trochanter by a transtrochanteric approach, we used a direct lateral approach with a partial osteotomy of the greater trochanter as reported by Dall [11]. In the present study, nonunion occurred in only 3 hips (2.0%: much lower than in our previous study [18.8%]). These hips were not associated with aseptic loosening of the acetabular component.

Last, to fix the grafted bone, we used 4.5-mm diameter bioresorbable poly(L-lactide) screws to minimize disturbance of any bone remodeling of the grafts. In our previous study, we fixed the grafted bone with 6.5-mm diameter crystalline alumina ceramic screws, and a rate of delayed trabecular reorientation was 11% at more than 36 months after operation [8]. In the present study, all the grafts were united with the host bone and remodeled within 36 months. Thus, although there has been no obvious evidence that bioinert alumina ceramic screws reduce bone union rates and remodeling, bioresorbable poly(L-lactide) screws with a smaller diameter used for grafted bone fixation might have the advantage of bone bonding and remodeling of the grafted bone.

In our previous study, we used a Charnley prosthesis and a variety of Bioceram implants with a 28 mm alumina ceramic head [8]. In the present study, we used a PHS KC prosthesis made of titanium alloy (Ti-6aluminum-4vanadium) with smooth surface roughness (0.3-0.4 μm) (Fig. 1A). The shape of this prosthesis resembles the Charnley prosthesis although the stem length is 1 cm longer for increased stability of the stem in the femoral medullary canal. The long-term result of this stem is excellent, and no aseptic loosening occurred during the follow-up period. We implanted a PHS KC prosthesis with a 22-mm alumina ceramic head. The 28-mm alumina ceramic head used in the previous study is the so-called old alumina. The average grain size is 5 μm, and surface roughness of the retrieved heads is the arithmetic mean roughness (Ra) = 0.028 ± 0.009 μm (the largest peak-to-valley height [Rmax] = 0.531 ± 0.270 μm) [17]. Since 1988, the manufacturer has made improvements in the properties of alumina ceramics, enabling the femoral head size to be reduced from 28-

mm diameter to 22 mm (current alumina). The current alumina is high-purity alumina containing more than 99.8% Al_2O_3 and has a much smaller grain size (average, 1.3 μm) than the old alumina. The surface roughness of the retrieved heads was Ra = 0.013 ± 0.003 μm (Rmax = 0.105 ± 0.006 μm), less than that of old alumina heads [17]. Our previous radiologic analyses of polyethylene wear showed a linear wear rate of 0.156 ± 0.078 mm/y for a 28-mm-old alumina ceramic head [17]. In contrast, the linear wear rate of the 22-mm current alumina ceramic head was reduced markedly to 0.090 ± 0.078 mm/y [17]. Thus, these improved implants with the smaller head size, resulting in less polyethylene wear and less osteolysis, have beneficial effects on the long-term success of cemented THA with acetabular bone grafting for patients with developmental dysplasia of the hip.

In Japan, osteoarthritis of the hip joint is mainly caused by developmental dysplasia or congenital dislocation of the hip. Because the acetabulum of these patients is small and shallow, acetabular bone grafting is required for adequate coverage of the acetabular component when the component is placed in the original acetabulum. Our improved surgical techniques and development of the prosthesis led to greater long-term success of the cemented THA for developmental dysplasia of the hip.

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