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Medial Protrusio Technique for Placement of a Porous-Coated, Hemispherical Acetabular Component without Cement in a Total Hip Arthroplasty in Patients Who Have Acetabular Dysplasia*

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ABSTRACT: Twenty-four hip replacements were performed with use of a medial protrusio technique to stabilize the fit of a hemispherical metal shell in the acetabulum in nineteen patients who had dysplasia of the hip. All of the hips were followed for a minimum of five years (average, seven years; range, five to thirteen years). Six of the hips were type I, seven were type II, eight were type III, and three were type IV according to the criteria of Crowe et al. The acetabular cup was implanted with the medial aspect of its dome beyond the Kohler line (drawn from the ischium along the ilioischial line) in all hips. An autogenous graft sculpted from the femoral head was used to cover 15 to 30 percent of the superolateral portion of the cup in one type-I hip, four type-III hips, and one type-IV hip. The need for these six bone grafts could have been avoided by reaming two to three millimeters more medially or by allowing 20 percent of the superolateral portion of the cup to be uncovered. Sixty to 84 percent of each bone graft was resorbed, effectively leaving the superolateral portion of the cup uncovered.

The amount of the surface of the cup that was beyond the Kohler line averaged 41 percent for the six type-I hips, 43 percent for the seven type-II hips, 41 percent for six of the type-III hips, and 44 percent for one of the type-IV hips. Crossing of the ilioischial and iliopubic lines was noted on the radiographs of two type-III and two type-IV hips. Radiographs of two type-I hips and one type-II hip showed 7 to 17 percent of the surface of the dome of the cup through the internal pelvic wall (beyond the iliopubic line).

None of the twenty-four metal shells were revised. A reoperation was performed on two hips to exchange a worn polyethylene insert, and three femoral components that had been fixed without cement were revised because of mechanical loosening. Wear averaged 0.26 millimeter per year in the fourteen hips that had a titanium femoral head and 0.09 millimeter per year in the nine hips that had a cobalt-chromium femoral head. The remaining hip had a ceramic femoral head, and the wear rate was 0.09 millimeter per year.

The medial protrusio technique is a predictable, reproducible method for obtaining fixation of a porous-coated, hemispherical acetabular component in a dysplastic acetabulum. The technique permits the use of a porous-coated (bone-ingrowth) component; avoids the use of support bone graft and thereby reduces the operative time; facilitates rehabilitation by permitting earlier weight-bearing of the hip; and permits the use of a modular bearing surface, which may allow future exchange of only this surface rather than revision of the entire acetabular component because of excessive wear.

The results of reconstruction of a dysplastic acetabulum with cementing of an acetabular component are well documented[8,9,11,17,19,20,22,25,27]. Increased rates of failure have been reported when bone graft has been used to provide superolateral coverage of the cup[16]. The best results have been reported when the medial acetabular wall has been maintained and no more than five millimeters of the cup has been left uncovered[2,8,11,19]. These results have been achieved with insertion of a small Charnley all-polyethylene component with cement. Charnley and Feagin[2] suggested that the rate of loosening of cemented acetabular components was decreased if the medial acetabular wall was kept intact and no more than five millimeters of the cup was uncovered superolaterally. Linde et al.[19] agreed with this suggestion after they had found an increased rate of failure of acetabular components that had been uncovered by more than five millimeters. McQueary and

*One or more of the authors has received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other nonprofit organization with which one or more of the authors is associated. Funds were received in total or partial support of the research or clinical study presented in this article. The funding source was the University of Southern California Center for Arthritis and Joint Implant Surgery Fund.

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Johnston[21] maintained the medial wall and filled the superolateral defect with bone cement rather than bone graft. Johnston et al.[18] studied the biomechanical forces associated with total hip replacement and recommended that the cup be placed as medially as possible without violation of the cortical bone of the cotyloid notch. Harris et al.[11], Rodriguez et al.[25], and Marti et al.[22] maintained the medial wall and used a bone graft to fill defects.

Harris and his colleagues initially recommended the use of a bone graft from the femoral head to provide superior coverage of the acetabular component when defects were present[11], but they later rescinded this recommendation because of high rates of revision (11 percent [five of forty-seven hips] at an average of seven years and 20 percent [nine of forty-six hips] at an average of twelve years)[16,17]. Failure was associated with the percentage of the cup that was covered with autogenous bone graft: sixteen (67 percent) of twenty-four cups with 40 percent coverage or more failed compared with three of fourteen cups with less than 40 percent coverage. Recently, several authors have recommended that a bone graft be used to cover components designed to be inserted with cement but that no more than 30 percent of the cup should be covered with the graft[17,25,29].

Dunn and Hess[7] recommended that, as an alternative technique, the medial wall of a dysplastic acetabulum be perforated purposefully to permit coverage of the acetabular component without bone-graft support. This technique resulted in placement of the medial aspect of the dome of the acetabular component medial to the Kohler line, as seen radiographically. Perforation of the medial acetabular wall requires breaking through the cortical bone of the cotyloid notch. The results for the initial seventeen patients in whom this technique was used were reported in 1978[13]. At an average of three years, none of the acetabular components had migrated. Hartofilakidis et al.[12] recently followed eighty-six hips for an average of seven years after insertion of a Charnley cup (Thackray, Leeds, United Kingdom) with the use of a medial protrusio technique and cement. At the time of follow-up, two of these cups had been revised and two other cups had progressive radiolucent lines. Whereas Dunn and Hess recommended controlled fracture of the medial acetabular wall with an osteotome, Hartofilakidis et al. perforated the wall with a reamer.

In revision hip operations in which the acetabular component is fixed without cement, osseous coverage of the component has often been achieved with protrusion of the medial aspect of the dome of the cup beyond the Kohler line and, therefore, beyond the level of the cortical bone of the cotyloid notch. This revision protrusio technique has provided stability and fixation of the cup without the need for a bone graft, and intermediate-term durability without migration of the component has been demonstrated[5].

The technique of protrusion of the medial aspect of the dome of the acetabular component into or beyond the medial wall has been used in patients who have dysplasia of the hip. The present study documents the principles of the medial protrusio technique and the results of its use for the fixation of porous-coated acetabular components without cement in dysplastic hips.

Materials and Methods

Over a period of eight years (1985 through 1992), twenty-six patients (thirty-three hips) had operative treatment of dysplasia of the hip. One patient (one hip) in whom the cup had been inserted with cement was excluded, leaving twenty-five patients (thirty-two hips) who had had acetabular reconstruction with a porous-coated (bone-ingrowth), hemispherical cup. The socket was placed superiorly in the pseudoacetabulum of one hip in a patient who had a bilateral total hip replacement. Therefore, the hemispherical acetabular component was placed in the anatomical acetabulum in twenty-five patients (thirty-one hips). In seven hips (five type-I, one type-II, and one type-III, according to the criteria of Crowe et al.[4]), the medial wall was not perforated. In the remaining twenty-four hips (nineteen patients), a medial protrusio technique was used for placement of the cup, and this was our study group. In one type-I hip, four type-III hips, and one type-IV hip, a bone graft was used to provide complete coverage.

The average age of the patients at the time of the index operation was forty-five years (range, twenty-two to sixty-nine years). The indication for the operation was a painful hip after failure of nonoperative treatment. No operative alternative to total hip replacement was believed to have been indicated for any of the patients. The patients were followed for an average of seven years (range, five to thirteen years).

All of the operations were performed through a posterolateral approach to the hip, as described previously[3]. Palpation of the pubis and the ischium and location of the cortical edge of the cotyloid notch allows identification of the true acetabulum. Soft tissue and any bone in the acetabular cavity are removed to expose the cotyloid notch. If the opening of the acetabulum is smaller than forty millimeters in diameter, a high-speed burr is used to shape the osseous cavity into a hemisphere. The anterior wall is hypoplastic and must be protected during the preparation of the bone. If the opening of the acetabulum is more than forty millimeters in diameter, the medial wall is reamed first. The superior wall of the acetabulum is a slope that must be converted to a hemisphere by superoposterior placement of a small reamer (forty to forty-two millimeters in diameter). The direction of reaming is in line with the desired axis of acetabular anteversion. The smallest reamer must be used first because the formation of a hemisphere with a superior rim requires reaming into the ilium. The initial use of a large reamer can destroy

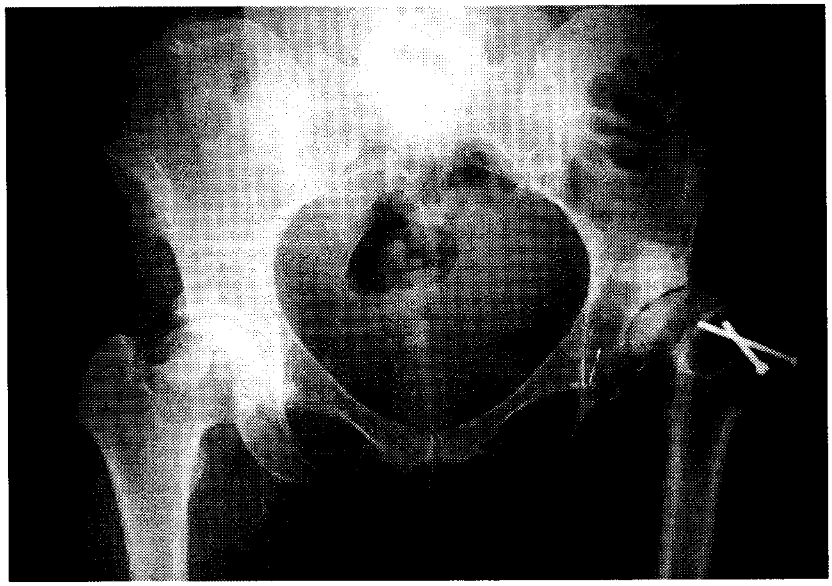

FIG. 1-A

Preoperative radiograph showing a left hip with type-III dysplasia according to the criteria of Crowe et al.[4].

the superior rim, necessitating a bone graft for adequate coverage.

If the depth of the osseous cavity after this preparation is not sufficient to permit stable so-called press-fit fixation of the acetabular component, the protrusio technique is used to deepen the cavity. Reaming is accomplished into or through the entire medial osseous acetabular wall, as needed, to provide a stable fit of the metal shell (Figs. 1-A and 1-B). The medial periosteum is usually left intact, but occasionally we have reamed through it, and the iliacus muscle is then seen in the base of the defect. When we did ream through the medial periosteum, the medial aspect of the dome was later seen to be beyond both the ilioischial and the iliopubic line on radiographs (Figs. 2-A and 2-B). Reaming is performed into the quadrilateral plate (beyond the Kohler line) rather than a controlled fracture being made with an osteotome, as recommended by Hess and Umber[13], because the hemispherical osseous cavity that is needed for the metal shell fixed without cement can be prepared more accurately with the reamer. This technique requires that the anterior and posterior acetabular bone

FIG. 1-B

Radiograph made six years postoperatively, showing medialization of the cup beyond the Kohler line.

FIG. 2-A

Preoperative radiograph showing a left hip with type-II dysplasia according to the criteria of Crowe et al.[4].

not be reamed too thin. The defect must remain only medially (no thinning of the acetabular rim), with no more than approximately 25 percent of the area of the acetabulum perforated; more extensive perforation can result in as much as approximately 45 percent of the surface area of the cup protruding beyond the Kohler line, as seen on radiographs (Figs. 1-A and 1-B). Thinning of the anterior and posterior walls or excessive (more than 25 percent) destruction of the medial wall weakens the hemispherical osseous acetabular cavity, and insertion of the press-fit metal shell can cause fracture through the anterior or posterior column, resulting in an unstable acetabular reconstruction. The osseous fragments produced by the reaming are collected, and the fat is removed by compressing the fragments in a lap sponge. The fragments from the reaming are then placed into the medial defect.

The trial component has to have so-called rim-fit fixation, with no more than 20 percent of the metal cup uncovered superolaterally. Because of the hypoplastic anterior wall, the anterior edge of the cup may extend beyond the osseous wall. If the edge does extend this

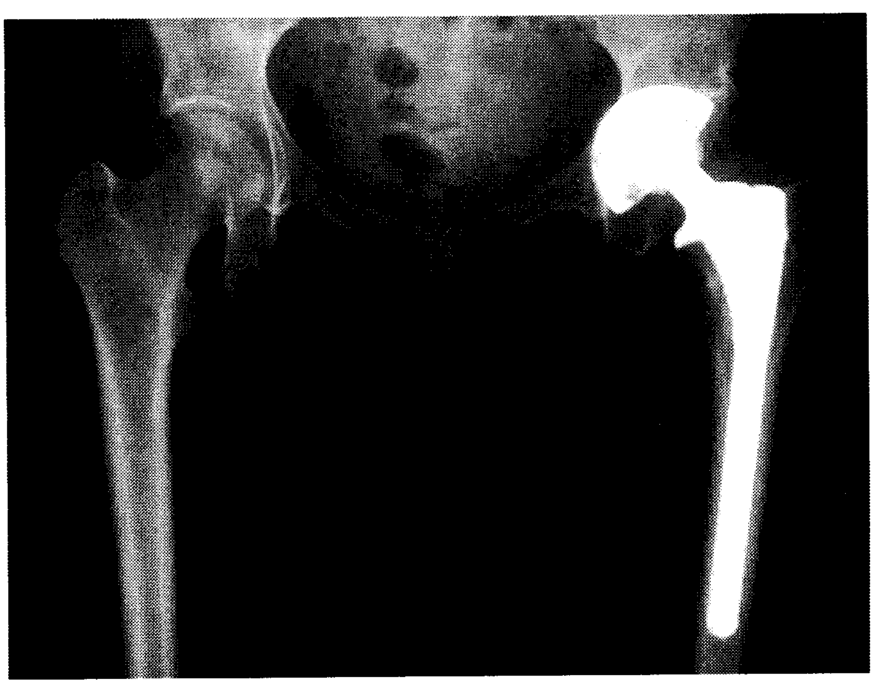

FIG. 2-B

Radiograph made six years postoperatively, showing the position of the cup medial to the Kohler line, reconstitution of the bone graft around the cup, and no evidence of a radiolucent line or osteolysis around the cup or the femoral component.

TABLE I
AVERAGE PREOPERATIVE AND POSTOPERATIVE HARRIS HIP SCORES[10]*

		Postop.			
	Preop.	Six Mos.	Two Yrs.	Five Yrs.	Most Recent Follow-up
Functional score	23 (9-33)	37 (15-47)	41 (23-47)	41 (28-47)	41 (25-47)
Limp score	3 (0-8)	8 (5-11)	9 (5-11)	9 (5-11)	9 (5-11)
Pain score	16 (10-30)	42 (30-44)	41 (30-44)	41 (30-44)	41 (30-44)
Total score	46 (26-63)	86 (53-100)	90 (61-100)	91 (72-100)	88 (64-100)

*The values are expressed as the average number of points, with the range in parentheses.

far, the iliopsoas tendon must be released to prevent abrasive contact of the iliopsoas muscle and tendon with the anterior wall of the cup (which can cause chronic pain in the groin). Press-fit stability was determined by the inability to move the trial shell manually, either by tilt or by rotation. With the anatomic porous replacement hip system, the trial acetabular component is one millimeter smaller than the actual acetabular component. A trial component that is the size of the previous reamer is used. Therefore, the actual acetabular component is one millimeter larger than the previous reamer. A hooded polyethylene insert is used, with the hood positioned to cover the inner surface of the prominent ischium.

In the hips in which a bone graft was used, the soft tissue was completely excised from the pseudoacetabulum and the ilium proximal to the anterolateral opening of the true acetabulum. The femoral head was prepared by removing any remaining articular cartilage and soft tissue and then was sculpted to fit the prepared osseous bed. It was fixed to the ilium with 6.5-millimeter-diameter titanium screws. The titanium screws may also pass through the bone graft, giving it additional fixation.

An anatomic porous replacement acetabular component was used in all of the hips. This hemispherical component is made of Ti-6Al-4V with a porous coating of sintered cancellous structured titanium that has an average pore size of 490 micrometers. The metal shell is a true hemisphere with an arc of 180 degrees. The porous coating covers the entire surface except for one centimeter at the central part of the dome. There is a cluster hole pattern for screw-holes, with seven, eight, or nine holes, depending on the size of the component. The component can be fixed with 6.5-millimeter-diameter titanium cancellous-bone screws. The acetabular fixation was augmented by screws in fourteen hips: five hips had two screws, three had three screws, and six had four screws.

An anatomic porous replacement femoral stem was fixed without cement in twenty-three hips. A custom stem was used in one hip because of the small size of the femur. Four femoral heads were thirty-two millimeters in diameter, ten were twenty-eight millimeters, nine were twenty-six millimeters, and one was twenty-two millimeters. Fourteen femoral heads were titanium, nine were cobalt-chromium, and one was ceramic.

Clinical evaluation of each patient included the determination of the Harris hip scores[10] preoperatively; at six months, two years, and five years postoperatively; and at the time of the most recent follow-up. The total Harris hip score and the individual functional score, limp score, and pain score were recorded (Table I).

The Ranawat triangle[24] was measured on preoperative radiographs to identify the correct size and position of the true acetabulum, and the position of the acetabular component relative to the true osseous acetabulum was measured on postoperative radiographs (Fig. 3). The Ranawat triangle was constructed by drawing parallel horizontal lines across the level of the iliac crest and the ischial tuberosities and then drawing a perpendicular line between these horizontal lines. This perpendicular line was drawn through a point located five millimeters lateral to the intersection of the Kohler and Shenton lines. The height of the pelvis was equal to the length of the perpendicular line, and the height of the acetabulum was equal to one-fifth of the height of the pelvis. The width of the acetabulum was equal to the height of the acetabulum, and the rim of the acetabulum was the hypotenuse of the triangle (Fig. 3).

The amount of medialization of the prosthetic femoral head — that is, the distance between the center of the osseous femoral head preoperatively and the center of the metal femoral head postoperatively — was measured. This medialization of the center of rotation of the femoral head was then compared among the four types[4] of dysplastic hips. On postoperative radiographs, the protrusio of the acetabular dome beyond the Kohler line was measured as the horizontal distance from the Kohler line to the most medial edge of the dome of the component (Fig. 3). A measurement margin of error of two millimeters was used to compensate for differences in rotation or tilt on the radiograph. The difference in magnification could be determined by the height of the acetabulum in the Ranawat triangle. The percentage of the surface of the cup that protruded beyond the Kohler line was measured as a percentage of the 180-degree arc of the cup; the percentage beyond the iliopubic bone (protruded into the pelvis) was also measured as a percentage of the 180-degree arc of the cup.

The theta angle (abduction angle) of the cup was measured from the horizontal line connecting both ischial tuberosities and a line parallel to the lateral opening

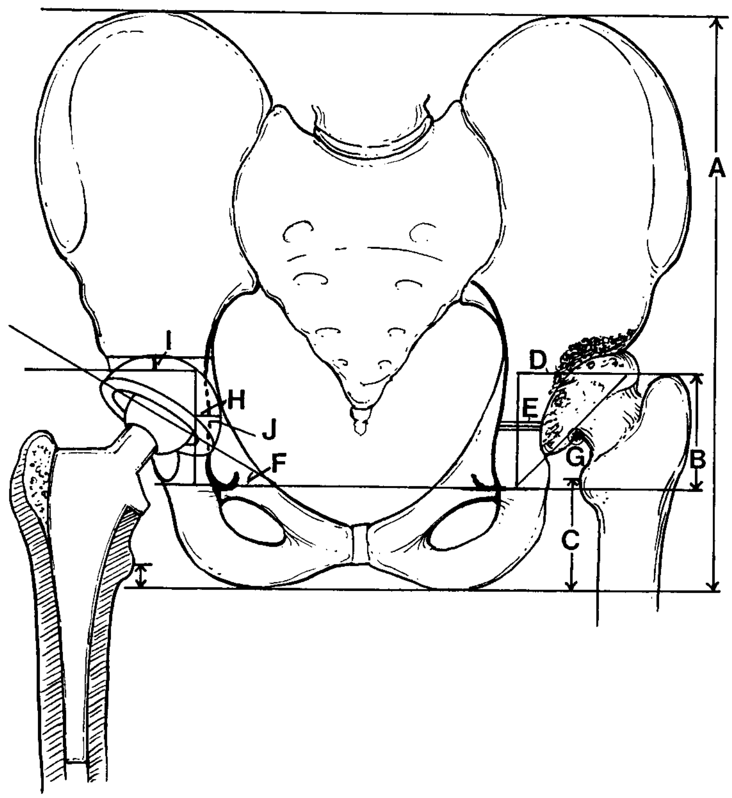

FIG. 3

The radiographic measurements included pelvic height (A), height of the true acetabulum (B), proximal migration of the lesser trochanter (C), Ranawat triangle (D), thickness of the medial wall (E), theta angle (F), medial femoral-neck junction (G), position of the cup medial to the Ranawat triangle (H), relationship of the cup to the superior border of the Ranawat triangle (I), and position of the cup medial to the Kohler line (J).

of the cup. The coverage of the acetabular component by the bone graft was measured by centering a protractor over the cup and measuring the arc of the cup that was covered by the graft as an angle. This angle was then divided into 180 degrees (the arc of the cup), and coverage by the graft was recorded as the percentage of coverage. The number of screws that were used to secure the graft was counted.

Polyethylene wear was measured with vernier calipers (margin of error, 0.02 millimeter) on the anteroposterior radiograph of the pelvis with use of a previously described technique[5,6]. Magnification was calculated from the known diameter of the metal femoral head. A line was drawn from the superior to the inferior edge of the metal acetabular component. The distance from the superior margin of the acetabular component to the femoral head then was subtracted from the distance from the inferior margin of the acetabular component to the femoral head, and this total was divided by two. Linear wear was calculated by subtracting this measurement on the radiograph made at three months from that on the radiograph made at the time of the most recent follow-up. This value was then divided by the number of years of follow-up to determine the annual rate of linear wear. The reason why linear wear was calculated by comparing the radiograph made at three months with that made at the time of the most recent follow-up, rather than by simply using the latter, was that the eccentricity of the femoral head on the radiograph made at three months was considered to be due to the creep that occurs in the polyethylene insert[6].

In sixteen hips, the polyethylene was less than eight millimeters thick. In fifteen of these hips, the metal shell was less than fifty millimeters in size. Each side of the metal shell was three millimeters thick (for a total of six millimeters) so that, with a forty-nine-millimeter shell and a twenty-eight-millimeter head, the polyethylene thickness would be 7.5 millimeters.

Loosening of the acetabular component was evaluated according to the criteria of Hodgkinson et al.[14]. The radiographic appearance of the interface was classified as type 0 if there was no demarcation, type 1 if the demarcation was of the outer one-third only, type 2 if the demarcation was of the outer one-third and the middle one-third, type 3 if there was complete demarcation, and type 4 if the socket had migrated and its position had changed.

Proximal migration of the femur was determined on the preoperative radiographs by measuring the superior displacement of the apex of the lesser trochanter from a horizontal line across the ischial tuberosities (Fig. 3). Five femora had migrated proximally fifty millimeters or more and had to be shortened. Two were graded as type III and three were graded as type IV according to the criteria of Crowe et al.[4]. Two hips had a subtrochanteric osteotomy for the shortening, and three had proximal shortening by resection of the entire femoral neck. Cement was not used to fix the femoral stem in any of these hips.

The degree of dysplasia was determined according to the classification system of Crowe et al.[4]. A horizontal line was drawn connecting the teardrops, and the vertical perpendicular distance from this line to the junction of the femoral head and neck was measured. To determine the amount of subluxation, this measurement was divided by the height of the dysplastic acetabulum. Type I meant that the femoral head had migrated proximally and laterally less than 50 percent; type II, 50 to 74 percent; and type III, 75 to 100 percent. Type IV was complete dislocation.

Statistical analysis consisted of a descriptive analysis (average, standard deviation, range, and variance for age, duration of follow-up, polyethylene wear, and medialization of the acetabular component) as well as a one-way analysis of variance to evaluate the relationship between wear and fixation of the cup, fixation of the stem, and size of the head. Pearson correlation analysis was used to evaluate the relationship between wear and age, number of screws, theta angle, and size of the acetabular cup, and the Student t test was used to evaluate the differences between two independent observers with regard to the measurement of polyethylene wear.

Results

All nineteen patients (twenty-four hips) were followed for a minimum of five years (average, seven years; range, five to thirteen years). No metal shell was revised. Three (13 percent) of the twenty-four femoral stems were revised. No patient had sciatic or femoral-nerve palsy. The average total Harris hip score and the functional, limp, and pain components were improved postoperatively. These improvements were maintained at all of the follow-up intervals (Table I). At the most recent follow-up evaluation (at which time three revisions of the femoral stem and two reoperations for exchange of the polyethylene liner had been performed), fifteen hips were rated as excellent and nine, as good. Two hips had had exchange of the polyethylene insert and a titanium femoral head. One hip had severe osteolysis of the acetabulum and wear of 4.4 millimeters at 8.5 years; the other had disassembly of the insert from the metal shell at 2.7 years and a rate of wear of 0.41 millimeter per year. There were three revisions of the femoral stem, two of which were done in patients who had had a subtrochanteric osteotomy for shortening of the femur. One of these patients had had a nonunion with necrosis of the proximal segment. The subtrochanteric osteotomy had been combined with a trochanteric osteotomy and release of the iliopsoas tendon so that no blood supply had been available to the proximal segment. The other patient had had healing of the subtrochanteric osteotomy site, but bone did not grow into the stem and the stem loosened. At the time of the operation, the polyethylene liner (for which the rate of wear had been 0.38 millimeter per year) was exchanged as well. The third revision of a femoral stem was associated with an incidental exchange of the titanium head and the polyethylene insert, for which the rate of wear had been 0.21 millimeter per year.

One acetabular component had a radiolucent line that was present in zone 3 and was less than two millimeters wide. There were no radiolucent lines adjacent to, and no measured migration of, the other twenty-three cups.

The rate of linear wear of the polyethylene in the twenty-four hips averaged 0.19 ± 0.16 millimeter per year. The fourteen hips with a titanium head had an average of 0.26 ± 0.16 millimeter of wear per year; the nine with a cobalt-chromium head, 0.09 ± 0.12 millimeter per year; and the one with a ceramic head, 0.09 millimeter per year. The interobserver error for wear measurements was 0.04 ± 0.05 millimeter, and no significant difference between the measurements of the two observers could be detected ($p = 0.41$). Nine hips had wear of more than 0.20 millimeter per year, and all had a titanium head. The total linear wear in the fourteen hips with a titanium head averaged 1.6 millimeters. Three of these hips had more than 0.30 millimeter of wear per year. In two, the polyethylene insert was exchanged. The third patient had acetabular osteolysis with wear of 0.51 millimeter per year, but no revision was performed for medical reasons. The relatively thin polyethylene insert contributed to the accelerated wear in these patients.

Six hips had been treated with a bone graft, with coverage that averaged 22 percent (range, 15 to 30 percent) of the superolateral aspect of the acetabular component. According to the criteria of Crowe et al.[4], one hip had type-I dysplasia; four, type-III; and one, type-IV. None of these hips had a revision during the follow-up period. In all six hips, additional medialization of the cup may have permitted stable fixation without the use of a bone graft. Sixty to 84 percent of the bone graft was resorbed by five years, effectively leaving the superolateral aspect of the cup uncovered.

In the six type-I hips, the cup was medialized an average of 5.1 ± 2.2 millimeters, with 41 ± 8 percent of the surface of the cup beyond the Kohler line. On the average, the cup was 3.4 ± 3.4 millimeters medial and 6.8 ± 6.1 millimeters superior to the Ranawat triangle. The center of the femoral head was medialized an average of 12.7 ± 4.2 millimeters. The average superolateral coverage of the cup with bone in the five hips without a bone graft was 96 percent. The theta angle (abduction angle) averaged 45 degrees, and the average size of the cup was fifty millimeters.

The cups in the seven hips with type-II dysplasia were medialized an average of 6.0 ± 3.3 millimeters, with 43 ± 6 percent of the surface beyond the Kohler line. The cups were an average of 5.5 ± 3.8 millimeters medial and 4.3 ± 7.3 millimeters superior to the Ranawat triangle. The center of the femoral head was medialized an average of 11.7 ± 13.5 millimeters. The average superolateral bone coverage in these seven hips (none of which had a bone graft) was 98 percent. The average theta angle was 49 degrees, and the average size of the cup was fifty-one millimeters.

Six of the eight hips with type-III dysplasia had an average of 3.0 ± 2.1 millimeters of medialization of the cup, with 41 ± 9 percent of the cup surface beyond the Kohler line; in the other two hips, the cup abutted crossed iliopubic and Kohler lines. The cups were an average of 5.8 ± 4.0 millimeters medial and 0.67 ± 9.3 millimeters inferior to the Ranawat triangle. The center of the femoral head was medialized an average of 26 ± 7.4 millimeters. The average superolateral bone coverage in the four hips without a bone graft was 99 percent. The average theta angle was 50 degrees, and the average cup size was forty-seven millimeters.

Of the three hips that had a type-IV dislocation, one had five millimeters of medialization of the cup with 44 percent of the cup surface beyond the Kohler line, and two had a cup that abutted crossed iliopubic and Kohler lines. The cups had an average of 5.8 ± 1.2 millimeters of medialization and were an average of 6.7 ± 1.9 millimeters superior to the Ranawat triangle. The center of the femoral head was medialized an average of 23 ± 8.4 millimeters. A bone graft was used in one hip, and the other two cups had 100 percent superolateral osseous coverage. The theta angle was 50 degrees, and the average cup size was forty-seven millimeters.

Discussion

Reconstruction of a dysplastic hip is the most difficult type of primary hip arthroplasty. Three different techniques have been used to accomplish osseous coverage of acetabular components fixed with cement. The most common method is the use of a small cup that can be cemented without more than five millimeters of the cup uncovered by bone[2]. A second technique is the use of bone cement to fill defects. In a report of fifty-nine hips treated with this technique, four (7 percent) were revised at an average of fifteen years[20,21]. The third technique involves the use of a bone graft to cover a defect. In a report of forty-six hips treated with this method, nine (20 percent) were revised and twenty-one (46 percent) had loosening of the cup at an average of twelve years[11,16,17]. To our knowledge, only one study in which bone grafts had been used to support more than 30 percent of the cup demonstrated a low rate of revision (two of twenty-seven hips at ten years)[22].

The principles for success with fixation with cement have been retention of the medial acetabular wall and leaving no more than five millimeters of the superolateral aspect of the cup uncovered by bone[2,11,19]. Most authors have recommended implantation in the anatomical acetabulum and the use of a smaller acetabular component to accomplish this coverage[1,2,4,8,19]. Linde et al.[19] followed Charnley implants fixed with cement for a median of nine years. Twelve (13 percent) of ninety-two cups that were within one centimeter of the true center were loose, whereas eleven (42 percent) of twenty-six sockets that had been placed proximal to the osseous roof were loose. Most often, type-IV dislocations[4] have necessitated the use of a bone graft to provide the desired coverage of the cup[8].

We know of four series in which acetabular components were fixed without cement in dysplastic hips[15,23,26,28]. None of those reports defined a consistently successful technique for obtaining predictable fixation. Hips with type-I dysplasia, according to the criteria of Crowe et al.[4], were included in those reports. Reconstruction with cement in hips with type-I dysplasia is not different from that type of reconstruction in osteoarthritic hips[4,8]. This is not true for fixation without cement because the osseous acetabulum must be converted to a hemisphere for a secure press-fit. We are not aware of any technique that has been consistently performed to accomplish this osseous conversion to a hemisphere to accommodate a cup fixed without cement.

The principles of fixation of acetabular components without cement in dysplastic hips differ from those of fixation with cement. A protrusio technique involving reaming into or through the medial acetabular wall was necessary in our series to provide a stable press-fit of the component. This technique was not needed for all of the type-I hips, but it was necessary for seven of the eight type-II hips and for all of the type-III and type-IV hips for which the arthroplasty was successful. No more than 5 percent of the superolateral aspect of the cup was uncovered; however, the arthroplasty can probably be successful with 20 to 30 percent left uncovered because 60 to 84 percent of the bone graft covering an average of 22 percent of the superolateral aspect of the cup was resorbed in the six hips treated with bone-grafting. Garvin et al.[9] suggested that 20 percent of the superolateral aspect of the cup can be left uncovered. In the six total hip arthroplasties that we performed with a bone graft, we could have obtained additional coverage and perhaps avoided the need for a bone graft if we had reamed farther into the medial wall.

In our series, the amount of medialization of the center of the femoral head tended to increase as the type of dysplasia[4] worsened, but the average percentage of the surface of the cup that was uncovered medially was approximately the same (41 to 44 percent) for all types. In the hips with severe dysplasia (types III and IV), the medialization of the center of the femoral head averaged twenty-five millimeters; this corresponds to the amount of medialization recommended by McQueary and Johnston[21]. Biomechanically, this is better than superior displacement of the femoral head[18]. In the series as a whole, the average position of the femoral head ranged from 0.67 millimeter inferior to 6.7 millimeters superior to the superior margin of the Ranawat triangle.

The modified protrusio technique for placement of an acetabular component without cement cannot be used in some type-IV hips with a very small true osseous acetabulum. A small all-polyethylene cup should be fixed with cement in these hips so that the polyethylene will be of adequate thickness. This reconstruction is probably improved by violating the medial wall if necessary. Johnston et al.[18] mathematically determined the benefit of medialization of the cup. In a subsequent series of severely dysplastic hips, McQueary and Johnston[21] found a lower prevalence of failure when the center of the head had been medialized by twenty-five millimeters or more, and they recommended that this be done if the medial wall can be left intact. We believe that medialization should be done, even if the medial wall cannot be left intact, for cups inserted with or without cement. The advantage is that the coverage of the cup with the osseous rim of the acetabulum is sufficient to provide intrinsic stability of the cup without a bone graft. Hess and Umber[13] and Hartofilakidis et al.[12] reported success with fixation of a Charnley cup with cement and violation of the medial wall.

In our study of hips treated with the protrusio technique, none of the acetabular components loosened and there was no migration associated with the perforation of the medial wall. Concern about migration was the primary reason why Charnley and Feagin[2] avoided perforation of the medial wall. In our series, osseous fragments that had been obtained from acetabular reaming and had been used as bone graft in the medial acetabular defects healed and formed a new medial wall that could be identified on radiographs (Fig. 2-B).

Our success with fixation without cement may not be better than that obtained after a similar period of follow-up after fixation of Charnley components with cement. Crowe et al.[4], at an average of four years, and McQueary and Johnston[21], at an average of eight years, reported no revisions because of loosening. However, there were no loose acetabular components in our study of fixation without cement, whereas the prevalence of loose (but not revised) cemented cups was six (10 percent) of sixty-one in the series of McQueary and Johnston[21], thirty-three (26 percent) of 129 in the series of Linde et al.[19], and twenty-one (27 percent) of seventy-eight in the series of Garcia-Cimbrelo and Munuera[8]. It should be noted that the comparison of our results with those in historical series presents difficulties because of differences in the durations of follow-up and in the time-periods during which the operations were performed.

In the present series, the primary causes for reoperation were the use of so-called first-generation stems[6] fixed without cement and the use of titanium femoral heads. In addition, we used mostly twenty-six and twenty-eight-millimeter femoral heads because in the 1980s we did not yet realize the importance of polyethylene thickness in the avoidance of accelerated wear. The size of the acetabular component needed for these dysplastic hips was almost always less than fifty millimeters, so the polyethylene thickness was almost always less than eight millimeters. The use of a twenty-two-millimeter femoral head has been most successful in arthroplasties performed with cement[17] because it permits a thick layer of polyethylene and a minimum of eight millimeters of polyethylene should be used with these modular components.

Shortening of the femur was necessary in five hips because the lesser trochanter was at least fifty millimeters proximal to the transischial line (Fig. 3). In two hips, the shortening was accomplished with use of a subtrochanteric osteotomy, and both of these hips had loosening of the stem. One of these hips also had a trochanteric osteotomy and release of the iliopsoas tendon; this isolated the proximal bone fragment from the blood supply, and the proximal segment became necrotic with a resultant nonunion. Subtrochanteric osteotomy in combination with trochanteric osteotomy may be contraindicated.

In the present study, we described a medial protrusio technique that provides predictable and durable fixation of cups in dysplastic acetabula. We recommend this technique when fixation of the socket without cement is desired. Because the acetabular component is almost always less than fifty millimeters in diameter, a twenty-two-millimeter cobalt-chromium femoral head should be used to allow adequate polyethylene thickness. The acetabular insert must be stable and congruent. Femoral shortening must be performed if the femur has migrated at least fifty millimeters proximally. The use of the protrusio technique will ease the performance of the acetabular reconstruction by eliminating the need for a bone graft.

References

1. **Cameron, H. U.; Botsford, D. J.;** and **Park, Y. S.:** Influence of the Crowe rating on the outcome of total hip arthroplasty in congenital hip dysplasia. *J. Arthroplasty,* 11: 582-587, 1996.
2. **Charnley, J.,** and **Feagin, J. A.:** Low-friction arthroplasty in congenital subluxation of the hip. *Clin. Orthop.,* 91: 98-113, 1973.
3. **Cohen, J. L.; Bindelglass, D. F.;** and **Dorr, L. D.:** Total hip replacement using the APR II system. *Tech. Orthop.,* 6: 40-58, 1991.
4. **Crowe, J. F.; Mani, V. J.;** and **Ranawat, C. S.:** Total hip replacement in congenital dislocation and dysplasia of the hip. *J. Bone and Joint Surg.,* 61-A: 15-23, Jan. 1979.
5. **Dorr, L. D.,** and **Wan, Z.:** Ten years of experience with porous acetabular components for revision surgery. *Clin. Orthop.,* 319: 191-200, 1995.